THE AMERICAN ROSE

JAMES L. TUCKER

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The "American" road — as it often *is*, and as it *might be.*

Earth roads. (*Frontispiece.*)

THE AMERICAN ROAD:

A NON-ENGINEERING MANUAL FOR PRACTICAL ROAD BUILDERS

BY

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Treating the Construction, Administration, and Economics of Improved
EARTH ROADS

NORMAN, OKLAHOMA
1916

Transport.

PREFACE

THIS book has a double purpose: First, to assist in forming an enlightened public opinion by presenting simple facts which underlie and are essential to sound practice in road-work, and to promote an understanding of and co-operation with this vast economic movement of road-building now moving over this country like a great wave of unprecedented magnitude. The subject-matter and its presentation will be easily understood by the non-technical reader.

Secondly, it aims to furnish the material for a brief correspondence course for actual road-builders, of the type now being offered thru the Extension Departments of a score of leading State Universities. This, however, appears to be the first effort in that particular direction.

CORRESPONDENCE USE.— In preparing this text on "*The American Road*," and questions thereon for correspondence instruction, the aim has been to encourage independent study and thought on this great national problem,— the construction of good and economical highways. Many questions are asked to which no answer is given,— possibly there are no satisfactory answers to them. The student of road-building whether officially connected with such work or not, comes only to well-ripened judgment after pondering its many phases carefully, diligently, and for a considerable period of time. Frequently what he most needs are live, suggestive ideas, or hints, whose complete application has not been worked out, or even fully stated. This text contains much of such suggestive material, a result of gleaning important constructive ideas from road experts all over our country. Many of the questions are designed to draw on the student's experience and general knowledge, and many, it is especially hoped, will stimulate his powers of observation.

Classes for Whom Intended.—Whether pursued with formal instruction or not, the material here collected will have great usefulness to graduate civil engineers who have given little attention to matters most characteristic of highway work, yet are called upon to assist in developing our national road system.

It is also aimed to especially assist that larger group, perhaps found in less responsible positions, who possess a limited technical education. Engaged in road-work, their lack of information on its numerous and complicated phases is discovered. This is a severe disadvantage to themselves, and also to the public in whose service they are, and whose interests they should be specially competent to safeguard.

A third class is that relatively inconspicuous but vastly important group of persons who actually build the roads, and guide and direct the labor of construction and maintenance. These, it is believed, will here find numberless practical and definite hints enabling them to obtain better and more economical results. They will also obtain a broadened interest and appreciation of their work, so often lost in the petty details of routine.

A fourth and likewise vastly important group may expect this text to be of special value and assistance. It consists of local officials, such as County Boards, or Commissioners. Their intelligent assistance and support of road engineers and other officials directly engaged in road-building would frequently permit the latter to do more, better, and more economical work with road funds than is now, unfortunately often the case. Still more unfortunately, this deficiency of results is often brought about by ignorance or antagonism from such board members, who having never themselves studied the principles of sound road-building, are therefore grievously affronted if it be suggested that there are any.

And lastly, there is a countless throng, not officially connected with road-work, consisting of tourists and others who regularly use and have a general interest in the roads,—in short the great American public. These it is who must furnish that *enlightened public opinion* upon which we must chiefly

rely for substantial progress toward the scientific building and administration of American Highways. In numberless instances such persons would be the prod and spur of lax officials and severe critics of wasteful and extravagant methods if only they were themselves sufficiently well-informed. To this class this text will particularly commend itself as a fair outline of modern highway problems, of the most advanced methods of dealing with them, and of promising methods for preventing the continued waste of millions of dollars of road money.

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(LEADING TOPICS ONLY)

NOTE: For correspondence instruction a course of twenty-four lessons comprising nearly 500 questions and problems has been prepared. For particulars address "The American Road," Norman, Oklahoma.

ILLUSTRATIONS

ILLUSTRATIONS

The American Road

CHAPTER I

GENERAL CONDITIONS AND PRELIMINARY STUDIES

Before studying detailed methods of road construction, it is sought to lay a foundation on general facts and present-day conditions. This chapter will discuss the scope of the American road problem, and the general theory of improvements. Then the part played by indifference of the public, and by incompetence in many nominal road-builders, with resulting enormous money wastes, will be sketched. Then we shall see the vital part which good roads play in rural development and that of the country's best citizenry, that the ultimate secret of low costs lies in wise spending, and that *good* roads are the best of investments. We shall then approach such construction problems as location, the study of grades, their economics, and finally show that the engineer is more nearly fitted by training to handle road work than any other person.

INTRODUCTION

1. Sources of Information. — It is not the present purpose to attempt a new or startling treatment of Country Highways. But little claim of originality is made. The Highway Departments of many progressive States put forth their experience in printed instructions to those actually carrying out road improvements. Leading engineers and other students of road problems have written many articles for engineering and Good Roads papers, or have presented the results of their study at Highway Conventions. Textbooks devoted to Highway Engineering steadily increase in number. For twenty years the Federal Government, thru its Office of Public Roads, has steadily carried on a campaign of education, publishing a large number of bulletins on all phases of highway work. There is seen, therefore, to be no dearth of material nor necessity for ignorance on the part of those who wish to learn.

2. Aim of Course. — This text, and the Correspondence Course based on it, aims to select and collect suitable material

from a wide range of these sources, and to arrange, edit, and co-ordinate the same so far as may be practicable in a brief treatment. The particular object and purpose of this work centers around the hope that these principles may be advantageously applied to improving country highways in Oklahoma, or in any other State, particularly in those cases where sufficient trained highway engineers are not regularly available. Truly, "He who runs *may* read," — if he wants to. No State can afford to annually waste three or four million dollars on her roads, thru unintelligent or inefficient application of road funds, as many are now doing. The existence of a suitable field for this course cannot be gainsaid.

How can the universal need for good roads be met? Evidently we can obtain them at a reasonable cost only by applying the collective experience and specialized knowledge of those devoting themselves to its problems. This text is designed to place such information and experience before those persons thru whom the public may be most benefited. Such a text should be short and designed to deal chiefly with that pressing need, common to most States of the Union, viz.: the development of *country roads*. Probably a chief benefit to be obtained from it will lie in the habit of studying and observing local problems and conditions developed in the minds of those who seriously study it.

3. Plan of Treatment. — The material presented will be developed in the following sequence: The general arguments for good roads, and then a summarization and discussion of the principles which have by experience been found to underlie successful road administration. Road economics, cost accounting, earthwork, and systems of road finance will be briefly treated, and the convict question considered. We shall then examine the general considerations applying to all sorts of road-building, such as location, ruling grades, and the vast importance played by all questions of drainage. Then follows in detail the methods of construction and maintenance of earth, sand-clay, "top-soil," and gravel roads as developed in various States, and a study of the materials which have been successfully used for these types of roads.

It is also hoped to indicate the directions wherein a further detailed study will most certainly repay the effort spent, and that this text will assist and lead to the construction and maintenance of the greatest possible extent of good roads at the least possible cost.

There is an outline treatment of road structures, such as the larger culverts and bridges, discussing elementary principles, the violation of which certainly leads to great waste of public money if not to the direct loss of human lives. The closing topic will be "Needed Legislation" and will undertake to suggest the legislative steps essential in any State to achieve the wisest and most economical expenditure of public money upon the highways.

4. — This is distinctly *not* a course in Highway Engineering, since it purposely avoids treating, excepting in the most superficial way, those subjects ordinarily covered in a resident school of civil engineering. This would include surveying, the design of steel bridges, the planning and construction of reinforced concrete, etc. A further distinction is that this text deals wholly with "cheap" roads, the kind that the West and Southwest must always chiefly build. It stops just short of the stone road (Macadam), with all its modern variations, as bituminous macadam, oiled macadam, bituminous concrete, and so into the various pavements, such as asphalt, in sheets or blocks, brick, wood, etc. For these types, in cost running up to $20,000 per mile, the direction of a skilled engineer is so obviously necessary that the material here presented would be of little value.

The necessity for the soundest of good engineering on "cheap" roads is herein consistently emphasized. The underlying reason is that where a limited amount of money is to be spent, usually true in country districts, the highest possible skill is required to get the greatest returns.

5. Scope of Country Road Problems. — There are two and one-quarter million miles of roads in the United States, but less than ten per cent of them are improved, and probably less than one-sixth are given systematic maintenance. Three-fourths of the traffic passes over one-fifth of the roads. Two-

thirds of our population live in the country. All our farm products must pass over country roads. If bad roads prevent country people getting to market, both the merchant and farmer lose, — but the town and city dwellers cannot fail to share in the loss. Therefore temporary expediency should not be the aim in road work, since good roads are a permanent necessity. They should be constructed with the best available materials, and as experience has shown to be most economical.

Ten years ago the amount of money appropriated as "State Aid" for highway work was approximately $2,000,000. For 1914 this increased to $43,000,000. In 1904 the total expenditures on highways in the United States was estimated at $75,000,000; for 1914 it exceeds $200,000,000. In the mid-Western section the expenditures in five years have easily quadrupled, and there the road-building program has hardly been started.

6. Earth Roads. — The term "earth roads" includes all forms of construction, or lack of it, below the grade of macadam, to secure a passageway for animals and vehicles. This should be again divided into "ordinary" and "improved" earth roads. Improved roads are those where a reasonable attempt has been made to secure a scientific location, and good drainage with low and fairly uniform grades, and where some intelligent effort has been made to overcome adverse natural conditions.

Since an overwhelming preponderance of our road mileage will always be of earth, what can science, or common sense, do for those who use the common country roads, built of local materials? Science can do, and is doing much for these roads wherever she is permitted to serve the community. This text is an effort in that direction.

Cheap roads are needed. Much agitation has assumed that the only good roads had some sort of costly hard surfacing, requiring eight to fifteen thousand dollars per mile. A survey of conditions in the West generally shows this to be an impossible viewpoint, and that road-improvement with local materials will be the chief need for a long time to come. The *dirt road* represents the first leg of nearly every journey, and

over it moves the traffic of the republic. When improved it will bring additional hundreds of thousands of acres under cultivation.

7. Possibilities Not Appreciated. —

"We have lived so long with our earth roads at their worst," says L. W. Page, of the U. S. Office of Public Roads, "that we fail to see that vast improvement *is* possible. This, too, need not jeopardize further improvements and still better roads, such as gravel or macadam. A good earth road is the stepping-stone to a hard road. It is the foundation of all future improvements, and with proper future plans may be constructed at once. A comparatively small annual outlay for maintenance will keep it in shape until funds are available for a hard surface. But to expect a good earth road where none has ever been *built* is like expecting a harvest from untilled ground. The earth road must be built, just as much as a gravel or macadam road must be built, and as much skill and experience is required to secure the best results for the money expended."

8. Logical Procedure. — "People are beginning to realize that even dirt-road construction requires the services of men who have been trained in this line of work. And in those counties which rely entirely on the labor tax for constructing their public roads, a great advance can be made if this labor is utilized under the supervision of an experienced road engineer.

"To make the best showing with the least possible money there must be applied the best skill available, not only in location, but in ascertaining the best material obtainable and in getting the best construction. No county should attempt important construction, or the issuance and expenditure of bond proceeds, without a competent engineer. Incompetent ones, tho costing but little for salary, have often been very expensive.

"It is not possible to emphasize too strongly the importance of carefully considering preliminary plans. Deciding the type of road to be built is of the utmost importance, for, if a mistake is made, the results obtained will be disappointing. A thoro study of the available materials in each locality is the first thing needed.

9. Theory of Road Improvements. — If the amount of money available is quite small, it may be necessary to limit expenditures, for a time, to a single road, but with sufficient money it should be expended on several important roads radiating from the towns. Possibly on a given road the greatest

benefit indicates the improvement of a particularly bad spot distant from town, but the general policy should be to first improve parts close in to town. As additional funds are available, each of these roads may be extended farther into the country to connect with similar radiating roads, built by other communities, providing the entire locality with a network of good roads.

While radiating roads of this kind benefit the farmer primarily, they help the town no less. In an agricultural community, without substantial manufacturing interests, the town is practically supported by the trade of the surrounding farmers. A good road, enabling the farmer to market to better advantage, increases his purchasing power, and so benefits the merchant in his trading town. Improved highways radiating from a town widen the area from within which the farmer may profitably market his products and buy his supplies in that town. Good roads also attract farm settlers, who also bring increased trade to the town.

10. Good Road Truisms. — Since restatement does not tarnish truth, the following facts may be again brought out:

Good roads, like good streets, make habitation along them most desirable; they enhance farm values, facilitate transportation, and add wealth to the producers and consumers of the country; they economize time and save wear and tear; they bring the country-side into beneficial touch with the city; they aid social, religious, educational, and industrial progress; they make better homes and tend to keep the young people on the farm; they promote social and commercial intercourse, and prevent intellectual stagnation in our rural population.

Bad roads mean abandoned farms, sparsely settled country districts, and congested cities. Good roads mean more cultivated farms, and cheaper food products for the city worker.

11. Usual Road Problems: Bridges. — To successfully attack any problem we must first know exactly what that problem is. Let us, for example, examine into the past conditions in Oklahoma, to see that which we desire to avoid. Her first Commissioner said $2,000,000 were spent annually for building

"tin" bridges, and about one-half a million spent on them annually for maintenance, even when most of them were comparatively new. This was two or three times as much as it normally should be, and this problem would never be adequately solved by having a multitude of untrained men in charge of this bridge-building, but only thru an effective State Highway Commission.

An adequate system of accounting is urged for the expenditures of public road and bridge money. There is here a great deal of "graft," even tho road officials are thoroly honest and act with the best of faith. It arises because the design and construction of good structures, particularly bridges and culverts, call for high-class engineering. In other words, local officials cannot in the very nature of things know whether or not a given bridge should cost $2,000 or $6,000. Too often they have been thoroly victimized in this manner and vast sums have been really, tho perhaps by them honestly, wasted. Adequate penalties should be provided for failure to report highway and bridge expenditures on the part of local officers. Provisions might well be made whereby the work could not be paid for until approved, accepted, and reported upon by a representative of the State Highway Commission.

It is especially desirable and important that the plans of all bridges and culverts, except the most insignificant ones, be checked-up by some competent engineer. Inspection and verification by him of the quality and quantity of the work done should be made a condition precedent to the issuance of warrants in payment. A modern bridge is an expensive product of centuries of engineering study and practice. Can the local official be supposed to judge competently whether the plans are adequate and safe, and not too costly, i. e., whether they are really worth the price asked? Or, granting that the plans and price are proper, can he be always certain that the work which the plans call for has been thoroly and conscientiously done? Skilled supervision and inspection is demanded if the public money is not to be squandered. The argument applies to the smaller township undertakings as well as to important State or county work. An effective State

Highway Commission should effect enormous savings in this field.

It has been often and aptly said that "An engineer is a man who can do for *one* dollar what *anybody* can do for two," and this economic view is precisely the one to take of the highway engineer. To lack the knowledge of what has been accomplished in similar circumstances elsewhere, puts any man under a great handicap. But after the engineer has competently done his part, there is still required the intelligent co-operation of the foreman, or supervisor, actually doing the work. If studied, this text will assist such a person in such co-operation. Such, in fact, is one of its chief aims.

12. Road Building an Engineering Problem. — To make a good road at all times free of dust, mud, and ruts, using local materials or at most those which can be cheaply and easily obtained, is an accomplishment calling in a marked degree for continuous study, for considerable engineering skill, and for the soundest judgment. Even then this general problem presents many difficulties not heretofore sufficiently considered or adequately studied, particularly in view of the widely differing materials and conditions in the various parts of this and other States. The successful farmer is not, perhaps, a skilled and experienced road builder. But there has been a stupendous waste of money, and vast discomfort and loss to road users in consequence of similar assumptions.

13. Cost of Indifference. — Take this example: Oklahoma is third in annual road and bridge expenditures of the several Southern States; in 1913 she spent three and one-third millions, cash, and "worked out" about three-quarters of a million of poll tax. No Southern State expends less than a million dollars annually on her roads and bridges in addition to the statute labor. Certainly no firm or corporation which did not court bankruptcy could expend these sums in such a haphazard fashion as do the people of these commonwealths. In 1915 Oklahoma recast her road law upon a progressive basis.

14. Vast Sums Annually Wasted: Why? — Money in vast sums is spent annually for maintenance of existing earth roads, but has given little resulting benefit, because of:

1. Lack of any set plan or system of road-work.

2. Choosing road officials for reasons other than their ability or interest in good roads.

3. Constantly changing road officials, laborers, and teams employed on the work.

4. Working roads at the wrong time of the year.

5. Adherence to an obsolete plan, using labor tax instead of cash tax.

15. Handicap of Incompetency. — It is estimated that in some States some five or six thousand persons are officially connected with administering the system of building and maintaining its public highways. Yet there are no requirements as to competency for these duties. There is no unity in method or organization, or state regulation, supervision, direction, or control. While the people are annually expending on public roads more than $200,000,000, a large percentage of the money, by reason of ignorance of proper methods and wasteful management, is not accomplishing any permanent results.

16. Effectiveness vs. Tradition. — To properly expend this great sum there should be employed a sufficient number of skilled, qualified men. They should be provided with necessary assistants and equipment, have placed at their disposal sufficient funds, and should be held responsible for results. There should be a well-connected chain of co-operation and supervision from the Federal authority down to the lowest township road official. This would be vastly better than depending upon tens of thousands of road officials whose knowledge of road-building is incidental to some other occupation.

17. Increase of Land Values. — There has been observed a most marked effect upon land values and in the change for progressiveness in communities thru which good roads run.

TYPICAL EXAMPLES. The following cases are cited in Bulletin No. 136 of the U. S. Office of Public Roads:

Manatee County, Florida, built 64 miles of macadam and shell road. From 1911 to 1912 land on the road increased in value $20 per acre, and land a mile away from the road showed an increase of $10 per acre.

Spottsylvania County, Virginia, improved 41 miles of road, and land which formerly sold on an average of $25.74 changed hands within three years at an average of $44.74 per acre.

In Dinwiddie County, Virginia, where 123 miles of road were built, land between five and ten miles from Petersburg advanced on an average from $15.25 to $30 an acre in about fifteen instances, while land ten miles from town increased $16.32 per acre in sixteen instances.

In Franklin County, New York, where 124 miles of road were built, eight pieces of land selected at random showed an increase of 27.8 per cent after the improved roads were built, while in Lee County, Virginia, which built 84 miles of road, land similarly advanced 25 per cent.

18. Community Development. — Spottsylvania County, two years after the main roads were improved with the proceeds of a $100,000 bond issue, showed a remarkable increase in general farm products as well as dairy and garden lines, showing the possibilities from an agricultural standpoint of "always good" roads. These roads were estimated to be returning dividends of more than 40 per cent as a freight proposition alone. Great advantages were derived from increased crop production, with consequent employment of more labor at a higher price and added prosperity to every one whose interests were connected with the community in an agricultural, business, or professional way.

19. Relation of Good Roads and Good Schools. — All educational activities or agencies must be more or less correlated, and they must be made accessible to the children. Where bad roads prevail most of the schools are of the antiquated one-room variety, usually located along bad roads at times nearly impassable. Thus irregular attendance restricts the educational opportunities of the child. Bad roads often impede the economic consolidation of these smaller schools, tho the consolidated school might give high-school courses, directed by a competent principal and corps of teachers. On the other hand, by improving the roads, consolidation is made possible, the schools are easily reached, the average attendance greater, and general efficiency is largely increased. Regular attendance at school means consistent and regular growth of both school and pupil, and consolidation means a maximum benefit to the pupils attending.

The National Education Association, too, is strong in the assertion that the rural educational problem will only be solved by consolidated schools. It must be centrally located, and should then serve as the center for neighborhood gather-

Before and after in Alabama,— cherty gravel road.

ngs, with a library and reading-room for the parents as well as the children. Lecures should be given, and the men of the community encouraged to gather and iscuss questions of community, State, and national importance.

21. Who should Build the Roads? — Good roads are of ital importance to city and country dwellers alike, and are as nuch a part of the country's transportation system as the elecric or steam railroad. We have reduced the cost of railroad hauls to one-tenth or one-twentieth of what it formerly was, nd are now moving rail traffic cheaper than anywhere else n the world, but with road freight we have failed to keep pace vith our long-distance transportation.

In many places communities have improved their roads ufficiently so that motor trucks from the city gather up farm roducts daily and the difference between the consumer's rice and that paid to the producer is small. The common aborer in the city as well as the man of wealth are heavily taxed rictims of bad roads, and it is just as equitable that they should ssist in their improvement as the farmer. This is the essence f the principle of "State Aid." The underlying aim should e to apportion the cost of road-building according to the enefits received.

22. Do Road Investments Pay? — It has been said that "we re the only nation which can afford poor roads," — but we re beginning to realize that we can no longer afford them. f the farmer takes account of his time, and the wear and tear n his vehicles and harness, made necessary by the larger umber of trips with smaller loads, the cost of hauling mounts p very fast and correspondingly reduces his profits. The onclusion is that no better investment can be made than utting money into judicious road-building.

23. Normal Growth of Country Population. — Iowa attributes her loss in country population to bad roads more than to ny other one factor. Her experience indicates that if farm roducts could be hauled over the roads any day in the year, eople could be gotten to cultivate five- and ten-acre tracts n an intensive way which would add greatly to the wealth of he population and to their numbers as well.

Ohio shows that in numbers her rural population did not keep

up in growth with her urban population, but that it was decreasing at an appreciable rate with the lapse of time. It is undoubtedly bad for the economic condition of a State to have its rural population steadily decrease while its city population steadily increases. If these interesting facts pertain to two of the most fertile and wealthy States of the Union, may we not safely assume that these conditions are pretty general? The moral is obvious.

24. "The Mud Waste." — Statistics show that more than double the tonnage passes over country roads than over the railroads. The Office of Public Roads at Washington says that the cost of hauling freight over our improved roads is 15 cents per ton-mile less than over ordinary dirt roads, which figures out a mud waste of over four hundred million dollars per annum.

Careful studies have shown that if two horses can just haul a given load over a road of dry and smooth broken stone, it will require three horses to move the same load if the same road is in a moist or dusty condition. But if the road is of earth and rutty and muddy, it would take five horses to pull it. If the road be covered with deep ruts and thick mud, eight horses will be required. But in still more unfavorable conditions of the road, ten horses would be required to perform the same work.

25. Cost of Hauling. — Several years ago, in Indiana, an estimate of the cost was made to haul loads over various types of road surfaces giving the following costs per ton per mile:

Asphalt	2.7	cents
Good macadam	8.0	"
Gravel road	8.8	"
Earth, hard and dry	18.0	"
Macadam with ruts	26.0	"
Wet sand	32.0	"
Earth roads, ruts and mud	39.0	"
Dry sand	64.0	"

The above estimate will vary in different localities, but it is safe to assume that the ratio of costs for the various types of roads will remain practically constant.

26. — The Department of Road Economics of the U. S. Office of Public Roads studies hauling costs, among numerous other things. These are some of the questions the Department asks and endeavors to answer: What returns, both in money and social service, are the roads giving us on our investment? How can the costs be reduced and the returns increased?

The answer to certain questions long disputed are already in sight. From studies made in Mississippi, Alabama, Florida, North and South Carolina, and Virginia it would appear that the cost of hauling the largest crops of the South — cotton and tobacco — to market over the unimproved roads is about 30 cents per ton-mile. Where the roads have been improved with a hard surface this cost is reduced to about 15 cents per ton-mile. In other words, good roads cut the farmer's principal hauling bill in two.

27. Drainage Wastes. — A leading Southern editorial writer says:

"A fruitful source of waste is in failing to employ proper methods of drainage when a road is improved or repaired. Expensive surfaces can be put on roads later, but good drainage makes a satisfactory roadbed for any kind of road surface. Formerly there were nowhere any carefully laid plans for road-improvement year by year. Nothing at all was done until certain parts of the road became practically impassable. Then there was a cry that something be done at once, but this is what it was: The road officials set aside money for the purpose, and the contract was given to some jobless man or to the local political leader. In either case the result was the same, — waste, heart-breaking waste.

"This occasional road-builder usually piled a few scraperfuls of dirt in the stretch of road where he was operating, making a rough, tumbled grade, over this scattered a little gravel, called the job completed, and drew his money. The first rain washed away the gravel; the second let wagon wheels mire to their hubs. Then there was another hue and cry, and the whole process was repeated at more or less regular intervals. Washouts, indeed, both of dirt and dollars!"

33. Waste by Choosing Wrong Road.—It is a prevalent but mistaken idea that to improve our main roads we must give them a costly hard surface. Often an agitation results in a demand on the township or county for such an improvement, and unfortunately several thousand dollars are often spent on a few miles of road having comparatively little traffic, while principal market roads are neglected. This unimportant road is perhaps only a small feeder and having usually received

but little maintenance may soon be about as poor as before improvement.

Assume that the sum of $5,000 was expended in the case just referred to, and four miles of road were improved. This same sum, allowing $100 per mile, would have improved fifty miles of dirt road for four years, or two hundred miles for one year. This improvement would have consisted of dragging and removing dead earth from the surface, crowning the road by means of the drag, cleaning gutters, and removing stones. Ruts could have been greatly reduced, drainage made possible, in itself working a permanent improvement, and, during the greater part of the year at least, the road would have been in fair condition.

34. Waste by Misapplication: Bond Issues. — The only part of a road that is really permanent is its location, or right of way. Money raised by a bond issue should be spent upon permanently located roads, the larger part on the roadbed or subgrade, and the smaller part in surfacing. The best advisers say that 65 per cent for the grading and possibly bridging, if of permanent types, and 35 per cent for the surfacing is about the proper proportion. This should apply particularly where the bond issues are long-termed; for at the maturity of the bonds the results obtained from the major portion are as good as when the work was first done. On the other hand, the surfacing material has probably been changed or renewed several times during the long period the bonds have run.

The money raised by small township bond issues has often been used in repairing old roads and on temporary location of new roads. In a few years the results first obtained may be entirely lost, and when the bonds become due, there is nothing to show for the money.

In all cases means should be provided for raising not only the bond interest, but also for an adequate sinking fund. It is a better plan to make the bonds serial and retire a part each year. (See § 249.)

When the State authorizes the issuing of county and township road bonds, it should stipulate that such money can only be used for construction work on permanent locations, and for the permanent part of such roads if the bonds run for a long term, and that the county or township must obligate itself to provide a special road tax for the interest and sinking fund, or to retire them if serial bonds.

35. Waste in Choice of Type. — A leading highway engineer says: "I believe more waste arises by using an improper type of road than otherwise. This does not mean too cheap roads have been built. Often it is the opposite error. More loss has probably been entailed by building too high a type of road than by building too low a type. Thus gravel roads properly maintained, are easier riding and more satisfactory to motorists than either a pavement or a bituminous macadam highway."

"The maintenance of a gravel road (in New Hampshire) does not exceed in any instance $200 per mile per year. The cost of construction is less than $5,000 per mile, and yet for motor traffic, they are more satisfactory than the $12,000 to $20,000-a-mile roads, which require an average maintenance of from six to eight hundred dollars per mile. Interest at 5 per cent makes the annual cost of the first, say $450; of the second, perhaps as much as $1,500 per mile.

"It is not necessary to expend such large amounts upon the surfacing of many thru highways. The drainage, the grading, and the alinement should be exactly the same upon the cheaper roads, as upon the pavement type, but the surfacing chosen for a road should be regulated solely by its traffic. This is the logical and correct solution of such problems, tho these factors have often been largely forgotten by those who have built a large mileage of our State highways.

36. Cheap *vs.* Expensive Roads. — Much is said about the economy of high-priced pavements; little on the value of low and medium-cost pavements. Road authorities should realize the financial and practical aspects of the problem and not permit themselves to be carried away by popular clamor.

Roads are much like automobiles that run over them, — to be had at almost any price. The cost of running, repairs, and upkeep is nearly proportional to the first cost of the car. It is the same with high-priced pavements. It is easy to gloss over the distant items of sinking-fund payments for renewal, the high repair costs when they become necessary, and the added interest requirements. The practical solution lies in choosing a type of construction that fulfills the greatest

number of fundamental conditions at a cost that can be afforded. It is the task of the road engineer or other official to decide in a specific case where between these extremes his road falls.

37. Choice of Surface. — The automobile is given, and rightly deserves, a great deal of consideration in building new roads and in rebuilding existing ones, yet the horse-drawn vehicle with steel tires should certainly not be overlooked. It is a good plan not to cater exclusively to either in building an important country road, but to plan and build the road to best meet the requirements for both under the given conditions. Consider the number of each using the road, and the probable increase of the next five or ten years. Thus experience has shown that it is useless to build a clay, or gravel, or even water-bound macadam road on a main traveled thorofare near a large city where automobiles will probably be two-thirds of the total road traffic. A hard-surfaced road is needed, with a binder that will not disintegrate under skidding, suction, or other characteristic traffic actions of inflated or solid rubber tires moving at high speeds.

38. Secret of Low Costs. — (See also § 7.) Highway improvement, like the growth of population, should be progressive. This means, first, the proper locating, grading, and drainage of the sub-base, or sub-grade. These are essentials to any good road.

This sub-base can be used as an earth road during the years when traffic is light and can be kept in serviceable condition by intelligent scraping and dragging after spring and fall rains at a cost of $20 a year per mile, or perhaps substantially less.

The second step is to make a sand-clay, or say a gravel road, when travel increases or funds become available, by applying several inches of sharp clean gravel after dragging and rolling the earth road. This can be done in most places for a few hundred dollars a mile and maintenance will cost about $100 a mile.

When the gravel road is outgrown, it forms an excellent foundation for a concrete surface. It is only necessary to loosen *the gravel, and* roll it to uniform compactness, then lay con-

crete to carry heavy traffic. This surface construction costs approximately $1.50 a square yard. Maintenance should not average more than $50 a mile annually.

The final step in progressive road-building, when heavy teaming and trucking predominate, is to lay vitrified brick or granite blocks, grouted with cement, on the concrete. Or, if part of the road should become a residence street or set apart as a boulevard, a quiet pavement of wood blocks, sheet asphalt, or asphalt blocks can be laid on the concrete.

This is the most practical and economical plan, providing for varying volumes and kinds of traffic over a century or more of use and involving no loss of investment in pavements that are excessively costly to maintain and which are not essential as a foundation in the final type of highway.

39. Spending Wisely. — Whatever the source of funds the necessity exists for spending wisely. What, if any, guiding rules are there? Sound thinkers agree that:

1. No road should be improved without some provision for its maintenance.

2. That all unprofitable work (i. e., things done for their beautifying effects alone) should be mostly avoided.

3. That all improvements not actually and positively needed should be omitted or postponed.

4. That the choice of pavement or road surfacing whose durability and ease of maintenance has not been ascertained in practice, be avoided if possible.

5. That unnecessary experiments be avoided.

40. Permanency of Investment. — The cost of earthwork, drainage, and foundation should be considered as *permanent;* the cost of road surfacing falls into a second or temporary class; while a third class embraces the money required annually for maintenance.

This shows plainly that there should be no hesitation in spending money judiciously and when needed for earthwork, under-drainage, and ditches; for well-designed, well-built concrete bridges and culverts; and for good appropriate foundations for structures. All money so expended adds value to the country, and prepares roads for their ultimate surfacing.

This kind of work well planned and well done lasts a very long time and requires little money annually for maintenance, but for instance it is a waste of money to use costly wearing coats on a substructure not well drained.

41. Road Locations. — A common fault of present earth roads is that they were never really located or laid out, but just happened. Designation by statute of the section lines often makes matters still worse, this sometimes being about the worst location the country affords. Grades are often unnecessarily steep, drainage is poor or lacking, and streams are crossed at unfavorable bridge sites.

It has been shown that a 60-ft. road on two sides of a section occupies 14.55 acres, while a diagonal road has but 10.28 acres, and saves .58 of a mile in distance. If a man lives four miles east and four miles south of his destination, he must travel 4.68 miles farther to go by the section lines than by diagonal roads. In locating a railroad the topography or "lay of the land" determines its location both with respect to the first cost of construction and subsequent cost of operation. Highway location should certainly proceed on the same principle.

To largely relocate these roads may be out of the question. The present general location must often be maintained because of farm improvements. But important betterments can often be made by modifying short sections. Thus instead of going over a steep hill it is often feasible to go around on an easy grade, with little or no added distance, and places difficult to drain can often be avoided by a slight detour. As these are permanent improvements they should be carefully planned to also meet the needs of the future. Should all future users be permanently inconvenienced because some landowner is slightly inconvenienced by having his farm cut in two pieces instead of one?

Enough has been said to show that matters of grade and alinement are usually interwoven with each other. It should be a compromise between the most desirable features in either case. A well-trained engineer can usually make the compromise with advantage to all interests concerned.

This relocation avoided a steep hill.

This relocation greatly improved both alignment and grade. Incidentally, it saved a bridge or two.

42. Locating a New Road. — In locating a new road certain principles should govern. First, the origin and terminal should be connected by the most direct line; second, the grades should be kept as low as possible; third, for economy's sake, the line should be so located as to reduce the amount of earthwork to a minimum, and similarly to reduce the number and size of bridges.

The factors requiring departure from a straight line are many. In crossing a ridge the lowest point in the summit is sought to avoid expensive cutting, or its alternative of steep grades; in following a valley, we keep well up on the hillside, to avoid bridging branch ravines and small water courses; a swamp or pond can frequently be avoided by swinging the line, saving the expense of a heavy fill; or a stream may be avoided by diverting the line, thus saving the cost of one or more bridges, and the damage due to frequent overflows.

The question of curvature was not of very great importance with slowly-moving vehicles, but now, a speed of twenty-five miles per hour is common and often exceeded. Whenever possible, the engineer should see that no curves of over six degrees are planned as a minimum, and as much flatter than this as natural conditions will permit. The six-degree curve is equivalent to a radius of about 900 ft. In the case of a road width of 30 ft., in a deep cut, this gives a "sight distance" of about 350 ft. in which to stop a car, or avoid collision. Where topographical conditions make this "sight distance" impracticable proper signs should be posted to warn the traveling public.

43. Right-of-Way. — Suppose the plans to have been completed as to the type and width of road surface. The necessary "right-of-way" needs next to be considered. In securing this the future must be carefully weighed, as the road is not being built for a few years, but for all time.

There is a difference of opinion as to the proper width to be taken over. It should not be less than twenty-five feet, as this would only be adequate for a small branch road, never having much traffic. On roads of much importance, it should not be less than fifty feet, and the main roads should have a right

of way of seventy-five to one hundred feet, or possibly more in special cases. A wide road will dry off quicker, as the wind and sun have a larger surface to work on. When ample space for a wide roadway, generous shoulders and deep gutters is provided, all these tend to make a better road than where there is a cramping of the roadway, shoulders, and gutters.

It should be further noted that at the top of hills and in the bottom of valleys where cuts up to 15 ft. in depth may eventually come, or fills of a dozen or more feet be made, greater width will be needed than elsewhere. For a common 24-ft. road at such points the right-of-way should not be less than 60 ft.

44. Road Width. — A vital point in road design is its width. It is almost axiomatic that the road widths should be in multiples of eight, as this is the allowance for each vehicle using the road. A road 8 ft. wide might properly be termed a lane, merely. Roads next higher in importance should be 16 ft. wide so two vehicles may have sufficient width in which to pass.

Twenty-four ft. permits two vehicles passing while the third was standing along the side of the road, — or two loads of hay or other bulky material can pass.

The fourth width, or 32 ft., permits two vehicles to stand along the sides and leaves sufficient space for two other vehicles to pass each other safely. These widths refer to the traveled carriage-way alone, no allowance being made for the accommodation of pedestrians, nor for any drainage structures.

For a roadway of sufficient width to accommodate a large volume of travel passing in both directions, 24 ft. may well be taken as the minimum allowable, and a prospect of an immediate increase of traffic calls for proper additional width, to be provided for in the original design. A road of generous width should be more easily maintained, since the traffic may then be distributed over a greater area.

45. Grades: Definitions. — "Grading" is the phrase used to designate the work of building the foundation of a road, and moving such earth, rock, or performing other operations *as this may require.* "Grade" means the slope taken length-

Before and after improvement, in Alabama.

wise of the road, as we look along it. It is usually expressed as a percentage, or the number of feet rise or fall in one hundred feet horizontally. Thus a 2 per cent grade means that we go up or go down 2 ft. in going 100 ft., or 2 yards in 100 yards, etc. The determination of the grades to be used and therefore the amount of grading to be done in improving any highway will depend largely upon the amount and nature of the travel, and the topographical conditions of the country traversed. Excessive grades increase the cost of transportation and also add a heavy burden to maintenance. Hence it will frequently be advantageous to lengthen a road to eliminate an excessive grade.

Since no greater load goes over a highway than is moved over the maximum grade, it is well to investigate and decide between what local points the greatest amount of travel exists. Upon the heaviest grades between such points we should then determine the equitable distribution of such money as is available for lessening grades. It is generally best to expend most of the money available in reducing the maximum grade and as little as is consistent with general conditions upon the lesser grades.

46. Effect of Grade. — *Ideal Conditions.* If a road has a perfectly smooth and hard surface, it is usually considered that an average work horse can pull a load of about 6200 lbs. on the level. A 3 per cent grade takes 2½ times as much work, or for one horse cuts the load to about 2500 lbs. A 5 per cent grade takes 3½ times as much work as on the level, or cuts the load to 1800 lbs. An 8 per cent grade takes 5 times as much work and cuts the load to practically 1200 lbs., while for a 10 per cent grade it takes 6 times the work, and lessens the load to practically 1000 lbs. But note that these figures are for a hard and smooth surface, — a condition never met on country roads.

47. Comparing Grades and Alinement. — Steep grades should be eliminated wherever possible, even if length must be added to the highway. In studying the relation of grade to distance, it can be shown that it would require as much energy to lift 1 ton 1 foot vertically, as to move one ton horizon-

tally along a road surface — which offers 100 lbs. of tractive resistance, — a distance of 20 ft. Theoretically, but not altogether practically, to save 1 foot of height the road may be lengthened 20 ft. without requiring any additional work in moving loads over it.

Unnecessary detours and heavy grades absorb the energy of engine or team, which is thus a dead loss to the community. If a road is straight with as light a grade as possible, the time and labor expended in traveling over it is then a minimum. But in a hilly country a road cannot well be straight and have a light grade at the same time. In such cases the sacrifice of straightness or grade should depend upon the predominant nature of the travel. Where horse-drawn vehicles predominate, the demand is for easy grades in preference to straight roads; where motor-vehicles predominate, the reduction of grades should give way to improvements of alinement, for the automobile has brought into highway work an additional requirement of safety in travel. They require the roads to have long easy curves which tend toward reducing damage to life and property. If the direct line, or location, also permits the engineer to eliminate unfavorable grades and obtain the required drainage it is the most economical.

48. Grades on Earth Roads. — For a *good* earth road, the load per horse on a 5 per cent grade becomes 1500 lbs. and for 10 per cent grade 930 lbs. But if such a road is only fair, the 5 per cent load falls to 900, and the 10 per cent to 660. If dry sand forms the road surface the figures are taken as being about 700 and 400 lbs., respectively. Comment is unnecessary on the meaning of these figures to the farmer.

It is suggested that at this point the student should measure the rates of grade on the hills or steep places in his vicinity and over which he hauls loads, and that he also observe the weight of loads he usually hauls over them to test the figures given. It will be seen, however, that a healthy and vigorous horse can take a spurt of effort and pull much more for a brief time than he can continue to do. This shows that the *length* of the grade will also greatly affect the maximum loads that *can be moved* over it by horses. The same may also be true

if a steam traction engine is used, since its steam-making capacity may be overtaxed before the end of a long steep grade is reached with a heavy load.

49. Measuring Rate of Grade. — Knowledge of the exact rate of grade involved is essential to any intelligent discussion of road work. It is very easy to find out the grade of an existing road, as follows:

Take an ordinary carpenter's level and fasten it in any convenient manner across or perpendicular to the top of a strip of board, or stick, in such a way that the top edge of the level is just 5 ft. from the other end of the stick. Now take this improvised leveling instrument to the hill whose grade is to be measured and stand in the road, facing up-hill. Put the end of your level-stick on the ground. Now center the level bubble and sight along the top of the level and mark the spot where your line of sight strikes the road in front of you. If this point is 100 ft. away, the road has a 5 per cent grade.

Similarily, if you had a 6-ft. mark on your level-stick, had placed the level at that point, sighted to the road in front of you, and found that your line of sight struck 100 ft. ahead, it would then be a 6 per cent grade. Or if the level were set at 4 ft. and it was found that the ground fell 4 ft. in 100 ft., that would be a 4 per cent grade.

The 5-ft. level-stick is the one most commonly used by engineers. Using it, if the sight strikes the road at 50 ft. it is then a 10 per cent grade; if at 40 ft., it is a $12\frac{1}{2}$ per cent grade; if in 80 ft., it is a 6 per cent grade. With this explanation the student road-builder should be able to measure any other grade which he may be interested in.

He should also be able to determine quite closely the depth of cutting or filling necessary in a given case to lessen an existing grade to any desired amount. Thus suppose we have a 9 per cent grade 200 ft. long and want to make it a 5 per cent grade. It is clear that the 9 per cent grade falls 18 ft. in going 200 ft. while the 5 per cent grade gives a drop of only 10 ft. in the same distance. Hence if we cut 4 ft. at the top of the grade and build up 4 ft. at the bottom, the 9 per cent has become a grade of 5 per cent, with the advantages already noted. How to find out what such an improvement would actually *cost* will be shown later.

51. Relative Values. — The relative value of alinement, grades, drainage, and cost depends upon the importance and class of the road. In weighing these factors we may classify roads as:

First: State and thru roads, constructed in sparsely settled or mountainous districts, and roads connecting the important trade centers of the State. The term trade centers should include not only the cities and towns but also the country tributary to them.

Second: County trunk roads, or the main highways in the

thickly settled districts, including the main arterial roads leading into the country districts.

Third: County feeders or branch roads. (Township roads.) As a rule, the State and thru roads are for light freight and tourist travel. The trunk roads carry both heavy freight and pleasure travel. The feeders are ordinarily freight roads with the heaviest loads usually being hauled towards the trunk system.

In making this classification the engineer must at all times consider the future possibilities of the country, and locate with them in view. While he usually constructs narrow dirt roads only, it is economy to get the permanent right-of-way and establish permanent grades with the first movement. The value of a unit of distance is hard to calculate, as the amount and class of traffic is so variable.

52. Alinement. — To arrive at the best alinement we must study the topography and attempt to strike an economic balance by weighing the value of distance and grades against cost of construction plus right-of-way and maintenance. Often the alinement has been fixed by topographical or other conditions before these questions have been considered. Thus in a large part of Oklahoma the existing roads commonly follow section lines. The ideal location would cut thru the fields and divide them into irregular pieces. When these roads are improved the locating engineer may have to overcome a strong local prejudice. Nevertheless the community can well afford to pay the land-owner a good price for the sake of getting the road into the right place, for $500 spent to secure a good right-of-way may save $5000 in construction, besides getting a cheaper road to maintain and to haul loads over.

53. Ruling Grade. — The selection of a maximum or "ruling" grade is of prime importance both in location and relocation. While numerous experiments have been made and theoretical tables of grades compiled, yet the actual traffic conditions, the topography of the country, and the money available will practically govern the selection of ruling grades.

If the country is comparatively level, it will be easy to construct a road with enough grade to drain well, but not *sufficient to* greatly oppose traffic. Moderate cutting and

filling will generally nearly balance each other and uses the material from cuts to raise low sections. However, the engineer should carefully estimate such quantities, and determine the most advantageous hauls, as this will materially affect the earth-work cost in building the sub-grade, regardless of the type of road that will be built.

The maximum grade is often fixed at 10 per cent, both for state roads and other permanent highways. It is common practice to work for 5 per cent, as the ruling grade everywhere; but the maximum may sometimes, in hilly or mountainous country, be called for. Before choosing the ruling grade the engineer should study the topography of the country and the ruling grade on the existing roads, between his location and the trade center. It will be useless to expend any considerable sum of money in reducing a certain grade, when a heavier grade exists or will be necessary in reaching the terminal. The ruling grade may, however, be increased as we get further from the trade centers.

On roads that are to remain in the first and third classes a ruling grade of 10 per cent is permissible; such roads as are or will come under the second class should have an 8 per cent grade, and where possible a 5 per cent ruling grade. In general large sums should not be spent to reduce a 5 per cent grade. Density of traffic should be the governing factor.

54. Drainage. — Of alinement, grades, and drainage of a road, drainage is often found to be the most important and is given first place in the distribution of the funds available for the work. Without proper drainage, any improvement in alinement, grade, or character of surface will fail to secure a permanent result. A much more extended consideration of this topic will be given in Chapter V.

55. Grade Economics. — Since few roads are level, and country of all degrees of steepness requires roads, it is evident that grades must be given a broad consideration. A vast amount has been written on this subject, much of it too technical, to be of benefit here. A hasty glance, however, brings out several questions of importance, to which the student's attention is directed.

1. What will be the present and future traffic demands upon the proposed improvement? This involves (*a*) Possible future developments in that territory from an industrial, agricultural, educational and social standpoint; and (*b*) the effect this road will have upon the general system of which it forms a part.

2. What type of traffic will use the road, and, allowing for development, what is its probable tonnage?

3. In which direction will the most tonnage move, and with what relation to market-periods? The aim is to give favorable grades, if possible, to that direction carrying the bulk of the traffic.

4. What differences in class of material and cost of construction where an easier grade and longer distance is compared with a steeper grade and shorter distance?

This brings out the point that the cost of roads on steep grades increases very rapidly with the increase of steepness of the grade because of the added cost of maintenance. It is estimated that, roughly speaking, the destructive effect of violent rains is four times as great on a 5 per cent grade as upon level ground, and nine times as severe upon a 10 per cent grade as upon level ground. Thus the cost of upkeep alone would in a very few years justify the cost of eliminating bad grades.

This also shows that the disposition of drainage is a most vital factor in the choice of maximum grades, because the steeper grades increase the velocity of the water, demand more skill in handling it, and if it is kept on the road will soon destroy it.

5. The safe descent of grades requires as much study as their ascent. They should be no steeper than a horse can safely descend at a trot. "Safety First."

6. With grade problems are coupled those of curvature or alinement, since often the steepest grades will have bad curves. Motor traffic requirements are becoming more and more exacting. A heavy grade with clear vision (see § 42) may be less dangerous than an easy grade with sharp curves and *obstructed vision.* Extended observation has shown that

grades in excess of 5 or 6 per cent are not satisfactory or economical for motor traffic, owing to the increased hazard, increased consumption of gasolene, and loss of power thru steepness. In frozen or icy weather motor traffic is extremely hazardous on grades exceeding 10 per cent and entirely unsafe on grades exceeding 16 per cent.

On the other hand, a stretch of 10 per cent grade does not reduce the value of the road as tho it were 10 per cent for its entire length, tho the simile of the chain and its weakest link is often applied. This is because a horse can for short distances, and for a short period, pull from two to four times as much as he can do continuously.

7. What effect does a difference in surfacing material make upon the power needed to haul a given load up a grade? Considerable experimenting has been done on this point. For a motor-truck it has been proved that the surface material had more effect than the grade, and that it took substantially the same power to haul up a 1 per cent grade in sand and loose stone as it took to haul the same load up a 27 per cent grade on concrete, asphalt, brick, or first-class macadam.

The U. S. Office of Public Roads, with a device called a dynamometer, has shown that as between clay and gravel on a $9\frac{1}{2}$ per cent grade, the saving of power is 24.2 per cent in favor of the gravel; that on a 5 per cent grade with sand, and then on sand-clay, of the same slope, the saving was 32 per cent; and the advantage of gravel over black dirt, all grades, average saving was 35.6 per cent. The dynamometer also showed that the traction thru loose sand was so heavy that a 15 per cent grade is required to double the level-grade draft upon it; while with stone-pavement a 2 per cent grade doubled the draft over the level-draft on same pavement.

56. Highway Engineering. — All the foregoing discussion goes to show that a vitally essential factor in the construction of country roads, if the greatest value is to be secured for the money expended, is competent engineering, i. e., the application of specialized knowledge, study, and observation to road-problems. The community, which, by reason of a false notion of saving money, employs an incompetent engineer invariably

finds in the long run, that the economy is very expensive, thru unnecessary amounts of money spent, and inadequate construction designed and carried out. The best services obtainable are always the cheapest in the end. Notice the remarks of the Governor of Georgia to his County Commissioners:

"Engineering supervision of road construction is absolutely necessary and this statement is proven every day, positively and negatively, in this State of Georgia.

"Let me say to you who are commissioned to spend the people's money, if you are in doubt as to the advisability of employing an engineer, observe closely the roads of a county built without an engineer and then those of another built by a man skilled in highway engineering. Don't employ a man whose only qualification is that he is cheap. His salary will be small but his mistakes will be many and expensive."

CHAPTER II

ROAD ECONOMICS

In its broadest meaning, the underlying idea of this chapter is to compare cost of road work with service rendered. In homely language, "Is the public getting what it is paying for, either in kind or quantity of service?" If it is not, we shall doubtless find that it is because one or more economic principles are being violated. As their truthfulness so nearly declares itself to a thoughtful person, the principles here stated are called axiomatic. This is also the reason why the treatment can be so brief, and yet so profitable.

A comprehensive discussion of road-building extends in numerous important directions. Yet our comprehension of the subject will be narrow and unsatisfactory unless we attempt to pursue each branch to its logical conclusion, and then to tie together and correlate the conclusions reached. This suggests what is meant by the phrase "road economics." Mr. J. E. Pennybacker is Chief of Road Economics of the U. S. Office of Public Roads, and has discussed this subject in part, as follows:

57.—Road economics is that branch of study which treats of the *cost* and *use* of a road as a public utility. These are the determining factors as to the amount of money to be spent, how it is to be obtained, how extinguish indebtedness incurred, the location of the improvement, its character, economy in managing the project, and the utilization of it for the economic benefit of the public.

The subject logically has two divisions: The first deals with those larger questions of legislation, finance, organization, road classification or selection, and the management of the completed road.

The second division is most important from the standpoint of economy and efficiency, as it relates to the actual work of construction. Examples would be the lowering of costs by

the intelligent use of labor-saving machinery; the keeping of adequate and efficient cost records so as to detect extravagance, incompetency, or dishonesty; the systematic and economical purchase of materials, and the use of any other measures whatsoever which would serve to produce the most satisfactory road at the lowest practicable outlay. (It thus appears that this whole text might well be termed a book on "Road Economics." The purpose of the present chapter is merely to re-state and recapitulate in brief form the essence of what is given a more extended treatment elsewhere.)

Legislation, to be effective, must be economically sound and correct, and the intelligent framing of road laws requires that the economic considerations applicable to the subject should be known and accepted by the legislators. Yet the effect of legislation will to a great extent depend upon the personal equation of those who are to carry out its requirements. This is illustrated by the extent of or failure to utilize such collateral agencies of the State, as convict labor, and the State schools for investigative and educational work.

58. — There are ten axiomatic propositions of road economics, which may be presented and then briefly explained, as follows:

1. That all who share in the benefits of road improvement should share proportionately in the burdens.

2. That the degree of improvement should be proportionate to the traffic importance of the road improved.

3. That the rate of payment or the rate of accumulation of the sinking fund on any public debt contracted for road improvement should approximately equal the rate of deterioration of the improvement.

4. That road building and maintenance comprise work requiring special qualifications on the part of those who direct it.

5. That responsibilities should be definite as to persons.

6. That continuous employment is more conducive to efficient service than intermittent and temporary employment.

7. That the specialists who direct road work should be appointed instead of elected; and that they should hold office *during efficiency* instead of for a fixed term.

8. That no road is wholly permanent and that it requires continuous upkeep, for which financial and supervisory provisions must be made.

9. That cash is a much more satisfactory form of tax than is labor.

10. That all agencies at the disposal of the State, capable of use in works of public improvement, should be so used, rather than in such commercial production as would conflict with private enterprise.

59. — Under the first proposition, note that the country road is no longer a mere local utility. Farm-products are essential to the city's existence; the city factory product finds its way to the most remote country districts. This interdependence implies sharing the burden of improving transportation facilities between them. Legislation should, therefore, provide for city taxation in aid of country road improvement, and automobile owners should contribute individually to the cost of our public roads.

The second proposition calls for the improvement of roads in proportion to their traffic importance. Too often costly improvements are distributed according to the dictates of a few influential citizens, or otherwise disposed of thru a cheerful, hap-hazard, and unintelligent indifference. The most heavily traveled roads should receive first attention and should be improved in a most substantial manner. It is comparatively easy to study a county road system and ascertain the traffic areas for each important road, much as one would show drainage areas for water-ways. The probable traffic in ton-miles for these traffic areas can be determined so as to establish with reasonable exactness the amount of outlay which the traffic would justify. This could be done at a cost nearly negligible, as compared to the cost of construction.

The third proposition, that debts should be paid off in proportion to the deterioration of the road, prevents incurring a debt outliving the utility it was designed to create. A road location, if intelligently made, should be permanent, and so likewise are all reduction of grades. Drainage features, if honestly and efficiently constructed, should be reasonably

permanent, and so is the foundation of the road if given adequate maintenance. (These factors are treated at considerable length elsewhere. See § 40.)

The fourth proposition which calls for the employment of specialists in road work is so nearly self-evident as to require little explanation. If the laws of a State require all persons selected to have immediate direction of road and bridge construction and maintenance to possess practical knowledge and experience, and if this fitness be tested by some sort of a competitive examination prescribed by an intelligent State Highway Department, or a civil service commission, the net result would undoubtedly be the saving of many millions of dollars of road revenues, and a wonderfully increased efficiency in our road system.

The fifth proposition, that responsibility should be definite as to persons, is aimed at the elimination of our present complex and cumbersome system of road management. If all this antiquated organization could be swept aside, and in its stead a new one with a few officials, endowed with authority and charged with responsibility, be created in each county, the beneficial effects would be most marked.

The sixth proposition is that continuous employment is more conducive to efficiency than temporary employment. A small force, easily moved, well trained, interested, subject to an effective discipline, would be infinitely more efficient than the unwieldy, careless, and non-trained forces now employed.

The seventh proposition, which calls for appointment rather than election, and for holding office during efficiency instead of for fixed terms, is designed to attract to the work men who look upon road-building as a life occupation or profession. A good engineer may be a very poor politician, and vice versa. A good highway engineer should not be spoiled by making him cater to popular fancy and whims. If he is the right man in the right place, it is absurd to limit him to a fixed term, any more than with a railroad employee, for example. His job is not a political reward. The county is buying his services and should get value received, and should continue to do so as long as he delivers the goods.

The eighth proposition, that no road is wholly permanent and that it requires continuous upkeep, is intended to impress upon legislative and administrative officials the necessity for making adequate financial provision to care for roads, no matter how well they are built.

The ninth proposition, that cash is a much more satisfactory form of tax than labor is put forth as a protest against that cherished heirloom known as "statute labor." If you provide an efficient highway engineer or county superintendent with a modest amount of cash, and let him select competent, efficient laborers, he can quadruple the effective results obtained by the same number of laborers under the old statute labor system.

The tenth proposition is that all possible State agencies should be used on works of public improvement instead of in commercial competition with non-State undertakings. This means the employment of convicts on road work, wherever possible, to the end that by their service they may discharge in part the debt they owe society.

This proposition also emphasizes the need for correlation of the State's various agencies for road work. Thus, a State Geologist should be helpful in the selection and location of road materials which the State affords. The laboratories at State Universities should be useful in testing materials; the university staff should be able to give theoretical training and instruction, and practical extension work; the state bureau of statistics and agriculture should help accumulate data useful in road work; and state civil service commissions would assist in inaugurating and conducting the merit system in filling positions requiring technical or practical experience and qualifications.

60. Logic and Sequence in Construction. — There is no method of road construction so good that there is not something almost as good and a little cheaper. Also the best which has been devised is still subject to improvement. There is a fairly well-graduated sequence between the poorest and best road construction, and that road is best for a given community which shows the most nearly perfect ratio between cost and value. Much energy is thus wasted in converting those who

can think only in terms of one type of improvement, irrespective of the local conditions. Adaptation is needful.

But the conditions and logic may change. As the feeders of any trunk line are improved, its value and utility is also increased. In ten years, the traffic-capacity of a given improvement may be entirely outgrown. Thus while it is unwise to construct macadam or a hard-surfaced road before the traffic warrants the expenditure, it is equally unwise to continue patching-up earth roads after the traffic has become larger than they can economically stand.

The wise construction is that which is ample for the present and immediate future, at the same time providing a suitable foundation for future improvements. A well-built earth road is but the necessary foundation for gravel or macadam; a worn-out macadam is a good foundation for concrete, and at last the concrete, should traffic demand it will serve as a suitable base for brick or asphalt.

CHAPTER III

ROAD ADMINISTRATION

To forward intelligently and economically a work so widespread as building roads an effective organization is plainly needed. The workers will be many, and the distances separating them such that direct supervision is difficult or impossible. The largest unit of organization is at present the State. A candid survey of results obtained abundantly justifies State Control of road work.

State Highway Commissions justify their existence only to the extent to which they educate the State's road-workers in effective and intelligent methods, and educate the public to a rational degree of support and co-operation. They are confronted with many problems of supervision and administration, solvable to the extent that the voters have given, or have withheld from them adequate and reasonable powers to carry out the purpose for which the Commission was created. We are bound to conclude that a well-trained organization for road work is indispensable, that the "spoils system" is out of place here as elsewhere in the public service, and that appointment and not election of officials solves a fundamental difficulty in advancing the art of building good roads.

This chapter seeks to indicate the relation and importance of all these factors to the main aim, the best roads for the least money, and concludes with the opinions of leading experts on road administration.

61. Past Practice. — Counties and townships in most States have voted large amounts for road purposes, the expenditure of which has not usually been under competent direction. With no provision for proper maintenance large sums were (and are) wasted and thrown away each year. Because of inadequacy of road laws little effort has been made by local officials to embody in the road improvement plans anything leading to the ultimate perfection of a State and county system of connected thorofares.

62. Effective Organization Needed. — In the rural districts, when State aid or State supervision is discussed, it is often thought this means eliminating all local control of highway construction and taking away from the voters the right of saying where and when their taxes shall be expended. This is

entirely wrong, since efficiency alone is sought. Everywhere the present tendency of highway law is to enlarge the unit of administration, and it is foolish to contend that the creation of an active State Highway Department means taking the control of road-building away from the people. In the first place, the State Aid or State Control roads are never likely to constitute more than a fifth of the total mileage and the balance will be locally administered. And, second, no Commission anywhere aims at anything more than to guarantee that all money put on the roads shall be most judiciously and effectively expended. Nor should we fail to observe that even with an active Commission there must be close co-operation between township, county, and State road officials if efficient service and economy is to be expected.

It is an echo from barbarism to demand that every function of government be carried out entirely by personal acquaintances. Civilization advances by increasing the range of social, commercial, and political relations. The school district yields to the township, the township to the county, and the county to the best interests of the State, while it has turned over to the general government many functions a hundred years ago jealously guarded as sacred rights.

63. What Has State Control Yielded? — A. N. Johnson, a leading expert, formerly Chief Highway Engineer for Illinois, sums up the results of State control of road work thus:

"It has yielded the development of a system of main highways adapted to modern motor freight traffic which promises great economic changes in both rural and urban life. It has increased the efficiency of local road officials in spending local taxes by preventing *useless* undertakings, by suggesting economic forms of construction, and increasing the economic service of the highways by concentrating expenditures on important roads and preventing waste on unimportant ones. It has been the medium of preventing numerous accidents and fatalities by constructing safe bridges, and the elimination or treatment of railroad grade crossings to greatly lessen the *danger from them*. And experience has demonstrated that

these ends are accomplished by State control of road work and *only by* such control."

64. Without a Commission. — The following summary sets forth *lack* of system:

1. Improper construction of roads.
2. Rapid deterioration of roads tho well constructed, due solely to the lack of proper supervision or maintenance.
3. No standardization of road construction and maintenance.
4. Dissatisfaction among people who pay for the roads.
5. A general dissatisfaction with engineers due to failure of local authorities to take care of the roads properly built by them.

An effective State Commission will:

1. Provide proper supervision for building and maintaining public roads.
2. Eventually give the State and counties an adequate system of highways.
3. Standardize road construction thruout the State.
4. Enlighten local officials toward bettering road conditions.
5. Perform engineering services for the counties.
6. Eventually save to the farmers a large part of the cost of hauling their products to market.

65. State Commission Methods. — With or without a classification of roads there are three ways in which the State can assist the counties and townships in developing improved highways.

First, by furnishing expert advice without having any authority whatever. This is the system formerly in vogue in Oklahoma, but substantially modified by the 1915 Road Law.

Second, by giving to the State Highway Commission and its engineering forces certain supervisory powers and authority to enforce its standards and rulings.

Third, by furnishing the Commission with funds and permitting it to go into partnership with the counties in building highways and bridges.

The third plan has been successfully followed in Wisconsin, Minnesota, and various other States. Iowa is a good example

of the second. Either plan does not antagonize the local authorities, but causes them to seek the aid and advice of the State Commission and brings about a most cordial relation between them. It also eliminates the chances of graft and corruption by making the plans, specifications and contracts subject to the inspection, review and approval of both the county and State authorities, thus guarding against the evils of ignorance or recklessness.

Under such a partnership arrangement the Highway Commission can show that it is a money saver. If it does not demonstrate that funds spent by it secure more for the money, there would be no possible excuse for its existence. It is simply a question of using the State government to the advantage of the various communities. If any one thing in the development of a national road system has been proven to be a success, it is the non-partisan State Highway Commission.

65a. Educational Field for Highway Departments. — The educational work to be carried on falls naturally into three groups:

First, training employees of the Highway Department. In cases where only a small headquarters staff is provided, much can be done to so direct and train them as to secure the greatest possible effectiveness from their labors.

But where the Department, in turn, is given direct supervision of County or Road District officials, general meetings, or institutes of road engineers and superintendents are invaluable. At such gatherings individual problems where information and assistance is required are brought up and disposed of, the discussion and interchange of ideas always resulting in greater interest and enthusiasm, as well as in securing direct information. The Department's standards, aims, and larger policies can then be explained, and active co-operation and support secured to a degree not otherwise obtainable.

Where, also, the Department has the opportunity to apply Civil Service methods towards engineering employees, there is always abundant outlet for its educational activities in training young engineer graduates who look toward road-building as a life work. This may mean either putting them into positions

where they will progressively acquire experience of a varied sort, or engaging in more formal educational work with them, as by correspondence methods, for example. There seems to be an important but hitherto neglected field here, in which State Highway Departments might, separately or in co-operation, prepare compact manuals of standard practice, showing the elements, or even elaborate developments of sound highway engineering, and then require those of their employees, not otherwise proficient, to take stated lessons and examinations therein. This is the method employed by the Bureau of Militia Affairs of the U. S. War Department, to secure technical proficiency among the militia officers of the National Guard. Its results there have been excellent and far-reaching.

The second group of people with whom State Departments can do great good in an educational way are elected road officials, especially those of a minor grade. Unfortunately, these are too often of limited education, or limited enthusiasm for new ideas, hence the work must be co-operative, tactful, and persistent, as these are usually a continually changing body. The methods already suggested can doubtless be modified to be extremely helpful in this field.

The third group is largest in number, and doubtless so in influence. It embraces the general public, including the taxpayer and the regular users of the roads. Here, education means *information*. No group of public officials can work effectively for the interests of a great number of people, especially if their opportunity for doing so rests upon the support and assistance of the public, unless, in turn, that public is well informed and in touch with just what the officials are trying to do, how they expect to accomplish it, and what has actually been done to benefit them. This is pre-eminently the case with a State Highway Department.

It follows that their bureau of information should always be open and always active in its work. Several Departments have begun to issue a periodical of some sort, often designated a "Service Bulletin," with this aim chiefly in view. With this others have co-ordinated illustrated lectures, demonstrations, and newspaper publicity. The aim is always the same, —

not self-glorification in those doing the work, but a seeking after the opportunity to render still greater and greater services to tax-payers, — an opportunity more likely to be granted when they are well informed as to existing conditions.

In conclusion, it may be said that in a broad sense the real and only purpose and work of a State Highway Department is the educational one to be carried out in every branch of highway work. The more candidly the facts are examined, the more forcibly is this truth borne home upon the observer.

66. Iowa Organization. — As a concrete illustration of what a long-continued fight for progressive legislation may accomplish, Iowa, since 1913, may be taken for profitable study. The outstanding facts are that she is getting "value received" on her ordinary road and bridge taxes, tho she does not as yet appropriate any money for "State Aid" roads. This is accomplished by giving certain broad and comprehensive powers to the State Highway Commission, and equally definite ones to county officers. She then classifies the roads and puts certain definite obligations upon township trustees; appoints, not elects, technical officers, and puts the whole of them under bond which may be forfeited if the work is accepted or paid for when it has not been done correctly, and according to the best knowledge and experience of the central authority, i. e., the State Commission. After a relatively brief period of operation the results achieved cause the opponents to such legislation to come out warmly in praise of it.

Let us examine the main features of the Iowa Code, beginning at the bottom. Many now advocate the abolishment of the *township unit* for road work. Much can be said in justification of such a measure. Iowa has shown that good results can be obtained with it provided reasonable supervision and assistance from the next higher road organization be provided. A principal *duty* of the township trustees is to appoint a Township Road Superintendent, "who shall have general supervision of all dragging and road repair work in the township road system." He alone is held responsible for thoro and efficient work on the township roads, and is "required to certify all bills for *dragging, maintenance* or repair work before warrants can be

drawn against the funds of the township system." Misfeasance in this respect makes him liable upon his bond.

Another chief duty is for them to *levy taxes* for the township roads, the amount being specified as not more than four mills for repair and maintenance, and one mill for a non-divertible dragging fund. Not less than 85 per cent nor more than 90 per cent of all the rural roads are by law made "Township Roads," the balance being "County Roads" to which township roads may be added by a specified procedure. It will be seen, therefore, that the Township Road Superintendent is responsible on his bond to his Trustees for repair work, dragging, and maintenance only, but permanent construction of any sort must be done under supervision of the County or District Engineer, who in turn is subject to the direct supervision of the State Highway Commission.

67. The County Commissioners have likewise well-defined and extremely important duties to perform. First they *must* appoint a County Engineer, subject to whatever qualifications they see fit to impose. A distinct improvement would seem to be possible here, in that the State Commission might advisedly specify minimum educational or professional requirements for such an officer, and often it would be a great advantage to consolidate two or more counties for these purposes, thus making him a District rather than a County Engineer. He is required to make the plans and specifications for all permanent work, under the dual supervision of the County and State Commissioners, and also to audit bills in payment for same before warrants can be drawn. Should he attach his certificate to work not in accordance with the official plans and specifications, he too becomes liable for that amount upon his bond. Needless to say, the financial responsibility under such a plan is complete, and of complete record, always accessible, so that no misapplication of tax funds is possible, or can be covered up.

The County Commissioners have exclusive jurisdiction over the county roads, already alluded to, and which are designated by them, in conjunction with the State Commission, and they also build the bridges and culverts for the township

roads. There is a perfectly clear line between the two classes of roads, however, so that the townships can always be assured that the money they raise will be spent on their own local roads and not be diverted.

68. — Before the County Board can proceed to erect a culvert or bridge, which according to the engineer's estimate will cost over $300, a resolution of necessity must be adopted, and a hearing set when the full particulars of the proposed construction must be set forth. This plan is intended to prevent construction of expensive bridges at places where they are not really necessary or wanted by the tax-payers.

For road and bridge purposes, their county *financial plan* seems to be as follows: eighty-five per cent of the motor-vehicle tax; two mills on all property outside incorporated towns for general road fund; a "permanent road district" tax of two mills, levied under certain conditions; and a millage tax for bonded indebtedness; finally there is a maximum levy of five mills on all property outside of cities of the first class for a county bridge fund.

69. — Finally, what are the duties of the *Iowa State Highway Commission?* They devise and adopt plans for construction and maintenance and furnish them to the counties. They inform, advise, and instruct all highway officials in the State, and make a public annual report to the Governor. They appoint such assistants as are necessary to carry on the work of the Commission, define their duties, fix the compensation and terminate the employment of such employees in their discretion, provide for all necessary fidelity bonds, and fix the amount of the same. It is their duty to investigate conditions in any county, and to report any violation of duty of road officials, whether of omission or commission, to the Attorney General, who is to take such steps as are by him deemed advisable. They must supervise the various township and county officers engaged in road and bridge work, approve the County Road System, or modifications thereof, approve plans and specifications for all *permanent* road and bridge work, including contracts for bridges costing more than $2000, and in co-operation with *the State Auditor* prepare and put into effect a uniform system

of accounts for road work in the State whereby the work of the Commission is really made effective. They have numerous other duties included under the general heads already enumerated.

The noteworthy and vital features of this system are that the interests of the tax-payer are insured at all important points. They get the maximum benefits from an engineering and economic stand-point at the minimum cost. In short, unreasonable prices for poor work are made a thing of the past, and a uniform, State-wide policy of road improvement is possible, wherein every community may have the advantage of the best services and skill the State can employ, assuring a high standard of work. Under it Iowa is now spending $10,000,000 a year, with satisfaction. What State does better?

70. State Commission's Problems. — But if we suppose a State Highway Commission with adequate power to be in existence, it should not be supposed that it at once can know all there is to be known about building the roads of its State. It must needs work out special problems as it meets them, including many difficult detailed ones of administration and design. Here, no other topic is of greater importance than bridge and culvert work.

Former Practice. All investigators of highway bridge and culvert work are agreed that the former administration of such work thruout the United States has been extremely unsatisfactory. Millions of dollars have been wasted.

There has been a general lack of centralized authority and responsibility in the past. The counties, the townships, and the cities have had partial and ill-defined authority in connection with the work. The man having charge usually had no training whatever for the work, and with the best of intentions could not avoid wasting money and failing to secure satisfactory structures.

71. Proper Practice. — In proper highway, bridge, and culvert administration probably the first question to be settled is the proper unit. For small States this may perhaps properly be the state, but in the Central West the county is undoubtedly the proper unit of administration. The county should employ a thoroly competent engineer to have full

charge of this work. Definite and complete plans and specifications should be placed on file in advance. Competitive bids should be secured for all contract work of importance. Construction should proceed under skilled inspectors. Absolutely complete records of cost should be kept.

All this work should be carried out under the general supervision of a State Highway Commission with real authority. Only in this way can the work of one county properly fit the others surrounding it, and only under active and competent central supervision can such work be carried on efficiently and economically.

72. Contracts *vs.* Day Labor Work. — Another question of general administration is whether it is advisable to construct all or any part of the highways, culverts, and bridges by day labor. The experience of Iowa indicates that the best results in ordinary culvert construction, both as to cost and quality, are being secured by day labor wherever a competent foreman can be secured to take charge. This eliminates the high overhead costs of private contractors, without any corresponding overhead cost to the county, which must in any case employ a county engineer and county auditor.

On the other hand, it is altogether probable that few if any counties can afford the large amount of contractors' plant or secure the services of the high-grade contractors' foreman required to build large and important highway bridges. Undoubtedly such structures can be best erected by contract. Wisconsin has had substantially the same experience, and has made extensive and organized use of day labor in highway work. Contrary to common experience, the results have been generally good. Important reasons for this, have no doubt, been: The lack of experienced contractors capable of undertaking first-class work; dividing the work into small parts, widely scattered; the widely varying types of construction; the independent character of the citizenship. With the increase of population, and the construction of more expensive and permanent types of surfacing, it is probable that contract work will become more economical.

All day-labor work done in each county should have the

closest scrutiny of the county engineer. There has always been great laxness in estimating the quantities and costs of materials handled in road-building operations. Thus, careful analysis has shown that in cases where day-work cost 65 or 70 cents per cubic yard for earth-work it should have easily been done for one-third that amount. In such cases the engineer should have full authority to stop the work unless a showing approaching contract prices could be made.

It is of course true that some engineers obtain splendid results from day labor, the work being of good quality and of low cost. This is due to securing capable foremen. These men demand good wages, and counties are often unwilling to economize in this direction. But high wages do not necessarily make a good man, and poor and extremely costly work has been known to result even in these cases.

73. Lump-Sum *vs.* Unit-Cost Contracts. — In general, the unit-cost contract is best since it reduces the element of chance and the contingencies to cover which the contractor must necessarily increase his bid. The community should not profit collectively thru the loss to an individual, hence the county should take the brunt of the risks incident upon any construction it proposes to undertake. In the long run such an assumption of risk will lessen the cost to the county, and it is the part of wisdom that the contract and specifications be so drawn that the risk to the contractor be as moderate as possible.

The publication of cost data, as well as preliminary cost estimates of the engineer, as required under the Oklahoma law, will on the one hand tend to prevent honest contractors from "going broke," while on the other hand it furnishes the best sort of safeguard against graft on the part of *any* officials, — even to those who make the estimate.

74. Timeliness of Plans. — The Commission can also greatly assist to expedite work generally by urging timeliness of planning. The winter months should be the time for getting ready the spring and summer's work. Every contract possible should be let in January or February. Then the county engineer has time to properly prepare for the letting. The County Commissioners are more likely to have time at this season

for giving contracts their proper attention. The contractors prefer it because business is quiet, and they have time to attend lettings at less expense to themselves. Also, the early lettings help them to make early purchases when material prices are best. Much of the material can be put on the ground before the season permits construction work, thus saving expense besides getting work done earlier in the season. Where day labor is largely used, large sums can be saved by making winter contracts for the summer's supply of cement, reinforcing and structural steel. All of this means that surveys should be pushed thru the winter, when possible, and that the engineering staff should be fully as busy thru the winter season as the summer, — perhaps even more so, because more money is saved by careful and intelligent planning than in any other way. The money saved from being thrown away is a double benefit to the tax-payers.

75. — The Commission's problem will also include such matters as the proper loadings to be allowed for in designing culverts and bridges. With the extensive use of large and heavy tractors, and the growth of motor trucking, coupled with the almost universal range of heavy, and rapidly-moving pleasure vehicles, — all combine to make practically sure that bridges designed for the common loads of 10 years ago are now unsafe. This is abundantly proven by hundreds of accidents on country bridges through just such causes.

The Commission must decide whether a given type of culvert should be classed as permanent, semi-permanent, or temporary, and under what conditions each can advisedly be used. Then there will be many special culvert problems. It takes a good highway engineer to proportion properly, locate, and design a highway culvert. Careful study should be given in each case to the special conditions.

A difficult special problem, for example, is where the difference in level between the upstream and downstream sides of the road is great. In such cases the water is almost certain to undermine the structure unless it is so designed as to break up entirely the force generated by the fall. In some cases gulches 30 to 50 ft. in depth have been formed within a few years in this way, in some instances thousands of dollars have been spent in the attempt to stay the progress of such a ditch, and in other cases a township road has practically been abandoned.

76. Problems of Supervision. — The road supervisor is usually uneducated and it is practically impossible for him to correctly account for the expenditure of large sums of money and equally impossible for him to keep cost accounts of his work. This condition is usually brought about by a disposition on the part of the Board of Supervisors or Commissioners to economize. So long as officials are elected because of their popularity rather than fitness, and paid a mere pittance for their services, we may expect many of them to be incompetent and perhaps dishonest.

Mr. Keller, the State Highway Engineer, describes a striking case in Alabama. A foreman was discharged. The Commissioner gave as a reason that he could look after the teams and hands and thereby save the county several dollars a month. The foreman resented his discharge and investigated the Commissioner's record. On a certain day this Commissioner drove seven miles to a small bridge where he made a contract to repair it for $1.50. A few days later he went back to inspect the work. The record of the Commissioners' court showed that cost of repairing was $1.50 and cost of inspection two days at $3 to be $6. Did this Commissioner do a dishonest act? He certainly was entitled to pay for at least the time consumed by himself, yet it is manifestly wrong for such a condition to exist that cost of supervision is four times that of construction or repair.

It is impossible to convince some county officials that an engineer can easily save his salary several times over by administering the road affairs of the county.

The rash and incompetent engineer is to a very great extent responsible for the prejudice against engineering supervision or good construction. There is no excuse for a county employing an incompetent man. The government, thru the Office of Public Roads, stands ready to aid any county in securing a good engineer, and every technical school of importance is devoting more and more attention to highway engineering.

76a. Trained Organization Needed. — To carry on highway work economically and upon a large scale the need of a trained and disciplined force is beyond doubt. The most important men are those at its head and these naturally will be engineers. Highway engineering in its theoretical requirements is simple enough. Except as to bridges, few problems arise requiring high mathematical training. There is, however, an almost unlimited field for the application of thoroly digested information that comes only with extended experience. This training

is best acquired on the work itself by young men with thoro technical preparation. The ideal road force must attract such men, must offer them a training and a future. Only in a large force, free from political control and with good chances for promotion for proven efficiency, can such conditions be insured.

All officials actually in charge of roads, no matter how important or unimportant their tasks, should form parts of a well-trained and systematically instructed force. Without such a force there are bound to occur many instances of waste by improper repair, or by petty graft, or thru stupid or ill-planned work. Hence co-operation and unity is required not only in the State force but among all minor officials charged with providing efficient road service. To-day the civil service system seems the only means of recruiting such a force. Whatever may be the shortcomings of this source of supply, it is preferable to political control. Promotion for efficiency in all grades gives the best results.

A highway engineer should have a good technical education, and for success he must be practical and diplomatic. He should be sober, honest, energetic, and think more about the work he is trying to do than the pay check he will receive at the end of the month. When taking charge of a county's road affairs he should convince the commissioners that he is a competent student of road-building and then prove it by doing good work. Unless he can convince the Board that he knows his business, he had better resign. Trouble often arises by want of a thoro understanding as to the engineer's duties. In his contract with a county, it should be clearly set forth what his duties are. If he is to be held responsible — and he should be for the success of his work — he should have full power to employ and discharge those under him.

77. How Not to Do. — During the past century hundreds of millions have been spent on our country roads, yet we have little to show for it. Why have such huge investments yielded so small permanent returns?

Competent observers agree that the fault lies chiefly in our *ancient system of road* administration, a direct legacy of the

feudal system, brought from Elizabeth's England by the colonists. By it we have paid road taxes by direct labor on the roads. And, unfortunately, the persons in charge of such work have seldom been chosen for their fitness; therefore enormous wastes have occurred.

Oklahoma's first Highway Commissioner said, "Did you ever hear of a man putting in an honest day's work on the roads? The idea of a man working out his road tax is the poorest piece of foolishness ever sanctioned by law. He might just as well work out his school tax. Tell him, 'This is your day to teach, — go down to school now and work out your school tax teaching the children.' What does he know about teaching? Nothing, of course! But he knows as much about teaching as about road-building. Every man ought to be required to pay his road tax in cash, like other taxes. Then the law should provide for the employment of a competent engineer and experienced road-builders who know how to construct roads along practical lines."

Similarly, the U. S. Department of Public Roads says: "The road work of this country is inefficient and inadequate. Pennsylvania, for example, had 3,000 townships, and the supervisor of each township was the road boss of that unit. There are probably 100,000 of these township road officers in the United States, each one exercising separate authority with no ranking head to direct groups of them. What would a great railroad do if each of its section bosses were permitted to buy all the material for constructing and maintaining his little piece of road?"

78. Merit System. — Continuous employment must be made a basic feature of our road administration if efficiency is to be obtained. No man can serve two masters or the interests of one will be sacrificed. Private enterprise requires good management to insure success. Public enterprise may be neglected as a rule with impunity because people in the aggregate do not look out for their own interests. Therefore, in any divided responsibilities the people will be the losers. Unquestionably the roads require constant attention, and only by continuous employment can such continuous attention be obtained.

The men employed must receive adequate compensation. The penny-wise and pound-foolish policy of saving money by employing a man who will give his services for the least compensation should be abandoned. An adequate scale of salaries and wages would attract to the work men who could effect economies and increase efficiency to such a degree as to save the outlay due to their extra compensation many times over.

79. Appointment Better than Election. — The men who actually construct and maintain roads should be appointed

instead of elected, and these men should be employed during their efficiency. The old political idea that a road office is a reward and that the reward should be passed around should be stamped out utterly and entirely. Its place should be filled by the principle of public welfare. If certain work is done for the benefit of the public, for which it pays, it is primary justice that the public pay only for value received. If the engineer or road superintendent renders to the county certain services which the county has agreed to purchase, it should continue to pay so long as the services are worth the purchase price.

80. Merit and Politics. — At an American Road Congress, Mr. Dana of the National Civil Service Reform League discussed civil-service reform in relation to road construction.

"Let me state some of the advantages that come from the employment of experts in road construction. It will save waste from poor plant, poor methods, use of the wrong materials, improper or insufficient sub-drainage, or surface drainage, insufficient foundation, waste in the supervision of labor, loss from insufficient specifications, and from failure to enforce good ones properly; from the employment of incompetent laborers, so as to give influential voters or friends of active politicians a job at the expense of the public at high pay, and remedy the inability to get a day's work for a day's pay."

81. Classification of Roads Required. — Whether or not an effective State Highway Commission is created, most authorities agree that the roads of the State should be divided into several classes, as a first and vital principle. The principal highways would be known as State Roads and be improved and maintained chiefly at the State's expense. They should be roads extending between centers like the more important cities and county seats of the State. They are of direct interest and financial benefit to the people of the whole State and their improvement is of direct importance to the entire State, furnishing ready communication between important points.

The second class of roads should be County Highways constructed and maintained at the expense of the county.

It should include roads of general use in the county but not a part of the main transportation system between centers of population.

The third class are Township Roads constructed and maintained by the local community. It should embrace only roads of a purely local interest from which the people of the State at large derive no direct benefit.

A proper financial system would then provide for the improvement of the principal highways from the State treasury; of the second class of highways from the county treasury; and of the third class from the district or township treasury. Thus the burden of taxation for road improvement would be distributed among the people in proportion to the benefits to be derived from them. To achieve this object is obviously just and equitable.

A classification resting upon a somewhat different viewpoint illustrates the principle that "Market Roads" radiating from trading centers improve both the market and the tributary country and should therefore receive first consideration. But there is no reason why the two schemes of classification cannot be harmonized, since where both plans coincide upon a given road that is simply the greater argument for making it a first-class highway.

83. Organization by County. — In any rational American system of road work there is a clearly defined place for a county organization, and the movement is steadily toward county units, supplemented by a State Highway Department. Such a system provides for a sustained policy and makes efficiency the object of its work. Every dollar expended is made to give a dollar's worth of returns. The roads are classified and the improvements adapted to the traffic requirements.

84. A Typical Plan. — A county may be divided into road districts each having an overseer in charge of the work therein. They work under direction of the County Engineer, who is superintendent of all road work in the county, whether done with district or county funds. The Engineer goes over each district and plans and directs where and how work is to be done. Overseers use a system of daily reports showing the

location and amount of each day's work done by him. The Engineer makes up pay rolls for each district from these daily reports and charges the cost to the proper mile, in a road-work record kept by him. All claims are checked and approved by him before being allowed by the County Board and a complete record of them is kept.

By this system it is possible to develop roads reaching out from the various towns to all parts of the county and to provide for their maintenance in a way that is impossible under the old overseer system, where each man is spending his district fund where and how he pleases.

The Engineer is also superintendent of dragging and makes contracts with the farmers when possible, or with other suitable persons. Blanks are furnished upon which the party doing the dragging records the date of the rain and the date and amount of the dragging. At the close of the season these reports are returned to the commissioners and the work is paid for. A common rate is 50 cents per round per mile.

The selection of the county as the unit of administration becomes more important as the course of time shows the necesity for strongly organized maintenance districts. Political units gather strength not so much by laws of establishment as by age and the habits of thinking of its citizens.

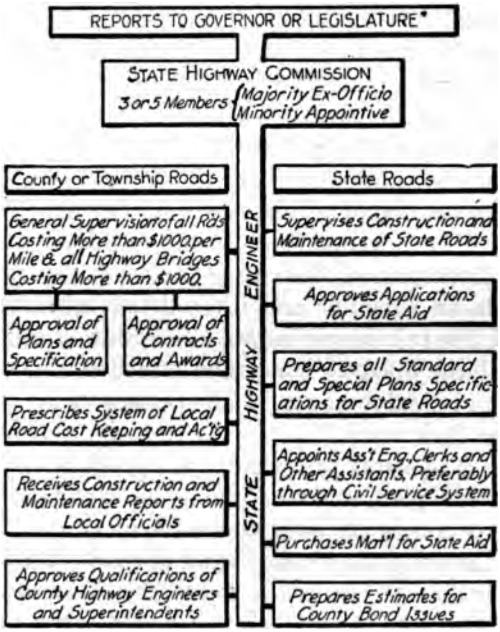
By selecting suitable officials under the regulations of State Commissions efficient executives may readily be secured. For maintenance work the continuous, personal supervision of a resident county engineer who is a capable executive is desirable. Furthermore, the desirability of undertaking new construction except under the close supervision of a State Commission is usually open to question.

It seems that the logical plan of organization for States having a large rural population is that of a small, efficient State Commission supervising the work of the various counties. This is simple and adapted to American conditions.

85. Experts on Administration. — George R. Wales, chief examiner of the United States Civil Service Commission, spoke on "Sound Administration of Public Service," at the American *Road Congress* at Atlanta, thus:

"No argument is needed that road construction should be placed in the hands of trained and competent men.

"A plan has been proposed whereby each State may take its road-building operations out of politics and place them under an administration which will insure 100 cents' worth of roadway for every dollar of taxation; an administration



SCOPE OF MODEL STATE HIGHWAY DEPARTMENT AND DUTIES OF ENGINEER

which will place road-building in the hands of technically trained experts who have made this science their life work; an administration which will enable the people to realize all those great benefits in education, prosperity, and improved country life that will result from an adequate system of modern highways.

"Briefly, the plan is for each State to place general supervision of its roads in a non-partisan board, under whom there

shall be a state highway engineer with assistants, and a highway engineer in each county, or a group of counties when a single county cannot afford to have an engineer, — all of these from the state highway engineer down to the county engineer to be appointed from among those graded highest in a competitive examination, testing the qualifications of all applicants for the places, and all of them to hold office during good behavior and efficient work."

L. W. Page, of the U. S. Office of Public Roads, says:

"Recapitulating briefly the intrinsic defects of our present system of road administration, I may say that they are:

"*First.* Extreme localization involving the maintenance of an unnecessarily large number of officials whose duties are similar and whose responsibilities are exceedingly vague.

"*Second.* The practice of requiring these officials to devote only a small fraction of their time to the work, thereby giving to the roads an irregular and intermittent attention.

"*Third.* The failure on the part of legislation or regulation to require that the officials who have direct charge of road construction and maintenance shall possess the qualifications essential for their work.

"*Fourth.* A general prevalence of the elective rather than the appointive plan, thereby giving an undue advantage to politicians as compared with engineers.

"*Fifth.* Limiting the term of office of road officials to definite terms rather than to the full period of their usefulness.

"*Sixth.* The influence of political considerations in determining who shall be employed.

"The remedy to my mind is the enactment of strict and clear-cut civil service legislation applicable to the particular road system in each State, and the conscientious and wise enforcement of such legislation. In the first place, a state highway engineer should be chosen by a non-partisan board and should hold office at the discretion of such board. All subordinate positions in the department should be filled by rigid competitive examinations without regard to party affiliations."

86. Pennsylvania Hints on Administration. — The Deputy Commissioner says to township officials:

"Organize promptly and properly.

"Appoint efficient officers.

"Appoint wide-awake roadmasters.

"See that they follow instructions.

"See that they attend your meetings and make their reports promptly and correctly.

"Transact all township business as a board at your regular meetings.

"Have your annual reports on file on or before January 1.

"Make your annual estimate carefully, and set aside a good percentage of your funds for permanent work.

"Endeavor to form at least the nucleus of a road force that will be given as steady work as possible.

"House your machinery in winter.

"Commence your work early in the spring.

"Crown your roads and dig adequate side-ditches.

"Drag your roads.

"Cut the brush and weeds from the sides of the roads and burn them, or otherwise remove them from the road.

"Straighten your roads.

"Reduce the grades.

"Flatten the curves.

"Erect index boards.

"Anything that is worth doing is worth doing well. Make your work a credit to your board and to your township."

87. Conclusions. — Extended study of road organizations has brought out the following elemental truths:

First. That our road problem is one of sufficient magnitude to demand adequate attention.

Second. That the chief cause of inefficiency is extreme localization, or applying the theory, "Every man is a Road-Builder."

Third. That this localization is based upon early colonial precedent crystallized in our road legislation and is wholly out of harmony with present conditions.

Fourth. That the remedy for localization lies in state control; and that this state control should extend to practically the entire road mileage of the State.

Fifth. That state road administration must be taken out of politics, and the best way to accomplish this result is thru the establishment of a non-partisan commission to select the principal officials, and the establishment of a competitive merit system of appointment for subordinate officials and employees.

Sixth. That the county road administration should be based upon the same principle of appointment by merit thru competitive qualification tests.

Seventh. That employment must be continuous in order to secure adequate results.

Eighth. That compensation commensurate with the qualifications of the appointees must be provided.

Ninth. That the men who have direct charge of construction and maintenance must be appointed rather than elected and must hold office during their efficiency instead of for fixed terms.

CHAPTER IV

CONVICTS AND ROAD WORK

This chapter gives reasons why convict labor is desirable. It is non-competitive with free labor; is of direct benefit to the State, already put to great expense for the prisoner. It benefits the prisoner, is more healthful, less demoralizing, and may be distinctly educational to him, since it furnishes an opportunity for the exercise of all grades of skill, intelligence, and physical capacity.

If a rational system of payment is worked out, with due reference to their obligations to the State, great benefits would result, to themselves in increasing their efficiency and self-respect, and by sharing in the support of their dependent families. The experience of certain States with convicts, and the costs of maintaining and equipping them, are given.

88. Convict Labor.— A variety of reasons, all good, point to the increasing use of convicts in road construction. Hence the subject is briefly examined here. In the first place, road-building is distinctively a public work in which the convict, otherwise maintained by the public in relatively unproductive labor, or idleness, can repay, at least in part, what it costs the general public to maintain him, and also what it has cost the State to prosecute and convict him,—often a large sum. In doing so he does not compete with free labor, as is apt to be the case in any line of manufacturing.

Secondly, if the true theory of prison administration lies in corrective training and education rather than vindictive punishment, and discipline for discipline's sake alone, and if the convict is after all inherently human, and not an animal of a different species, as seems to have been assumed heretofore, then it is vastly better for him also to be working in the open, under conditions of good sanitation, than to be housed within prison walls or factory. This view further assumes that his morals, if defective, will become normal sooner if his health is good and his body robust, than if they depend upon a body debilitated because habitually housed under less healthy

conditions. And in view of his relations to society after his release, (as affected by the mental attitude with which he rejoins it), it would seem that society is abundantly justified in at least a moderate degree of care for his welfare, simply as a matter of insurance. He is still a human being, frequently of a type weak but not truly vicious, and capable of being reclaimed to society as easily as being completely ruined by a prison sentence.

It can be readily shown that work upon the State's highways under an intelligently-planned and humanely-administered convict system is a long step ahead in the solution of these problems, especially if the idea of discharging an indebtedness to the State can be developed, and that when discharged from prison normal citizenship is recovered.

89.— In the third place, this convict labor can readily be made a great economic asset to the counties or State employing it. This is well illustrated in the Road Law of Oklahoma, enacted in 1915. This provides that all those expenses to which the State would normally be put for maintaining a prisoner in the State's Prison, shall be continued when the prisoner is on road work. This includes food, clothing, medical attention, and all the costs of his shelter and custody. As the State would also normally purchase and own equipment for factory employment for him, it may substitute road-making tools and machinery in place of it. Continued observation shows that the first-named costs generally run from 50 to 60 cents per man per day.

How then may a county specially profit by this arrangement? The county is to pay the costs of transportation from the time prisoners leave until they return to the prison, fuel, feed for all work-animals, ordinary running supplies, and current repairs to the plant used. All road-building materials are of course supplied by it. Subject to these conditions, the labor is entirely free to the county. In other words most of the plant charges and practically all of the labor charges are borne by the State. Needless to say, the local Road and Bridge Funds, relieved of these major charges, should extend much farther than would otherwise be possible.

Mr. J. H. Pratt, Geologist and Engineer for North Carolina, a leading good roads worker of the South, has written fully and convincingly on various phases of convict road work, in part as follows:

"I take it for granted that all believe the convict should do some work. What better work for him than building public roads? Considering the scarcity of labor in our rural sections, this plan will practically never come into competition with free labor."

90. Improvement of the Convict.— It engages him in healthy labor, outdoors. It is hard work and should not be imposed upon the physically unfit. Statistics show the health of road-workers to be better than in any other class of convicts. But this of course implies that the camp shall be administered upon a semi-military basis as to cleanliness, general sanitation, with wholesomeness and sufficiency of food. This is readily obtained and abuses prevented from creeping in under competent supervision from State health and penological authorities.

91. "Improvement of Road Work.— The use of convicts in road construction permits of a better organization of road forces, and one in which there is greater permanency than is usually the case with free labor. Free labor is at times practically impossible to obtain, nor can it be retained long enuf ta be trained so as to be most effective. But after a few months' work together a convict squad becomes pretty efficient, and performs its work with intelligence and care."

92. All Types of Employment.— There is always a lot of heavy and rough mechanical work, such as running drills, stone-crushers, traction engines, rollers, etc., where after a time men with any aptitude become competent and valuable mechanics. Then there is blacksmith work, such as shoeing animals, sharpening drills, picks, mattocks, and repairing drags, scrapers, chains, etc. There is always, too, a considerable number of teamsters required, where the less strong and active men can be suitably employed. Cooks and kitchen help are needed, as well as special sanitary details, wherein work could be used as a disciplinary measure.

For the most intelligent and competent executives, there would be an abundant outlet as foremen of concrete gangs, rough carpenter work, special repair jobs, etc., while for those with sufficient education and clerical ability there would always be a great deal of bookkeeping looking toward necessary records of a personal sort, the cost and checking of supplies both for the commissary, for plant and machinery, and road-building materials purchased by the county, and for securing and maintaining cost records on every phase of the work, without which waste, extravagance, or graft is certain to occasionally creep in. Thus while road work is the best possible work for the ordinary criminal, it is equally good from every standpoint for the better educated and more intelligent convicts as well.

93. Tramp Nuisance.— As Mr. Pratt says, while it is true that there are a certain number of floating individuals who are the victims of unfortunate circumstances, it is further true that there is a less worthy class who drift about, chiefly because they despise work. Weeks or months in jail or prison is a rather comfortable existence for them, especially during cold weather. Systematic road work for these vagrants would undoubtedly benefit them, and also promptly free the community from their nuisance.

94. Prisoner's Pay.— At this point an interesting question involving both ethics and economics arises. Should the prisoner be paid, and if so, how much? As between the county and the State, there seems to be no valid reason why the county should not refund to the State the total actual expense of maintaining the prisoner in road work. If this is not done, the county which does *not* elect to use convicts (or perforce, was not able to get any, because the demand was so great that gangs of practicable size could not be furnished wherever requested), is making a present to the second county of that part of its general taxes which go to supporting the prison. This goes to the benefit of the second county's roads exclusively, and for which the first county is precluded from getting any return whatsoever.

The second question relates to the efficiency of the laborer *in part. Granting* that the county should pay the State for

its state-convict labor, how much should it pay? It has been assumed that the convict cannot be made to do more than half a free man's work. Whether or not this is correct, it appears that unless the county pays in addition to the cost of maintaining him, the balance up to what free labor would cost to do the same amount of work, even discounted 50% as suggested above, then the county using this labor is still indebted to the other non-using county, as suggested above.

In the third place, should the convict be paid something himself, as an incentive to better work, to enhance his self-respect, and to permit him by such labor to contribute something toward the support of those dependent upon him, as well as purchase for himself certain comforts or luxuries which the State would not ordinarily furnish? On the above basis, assuming that free labor can be secured at $1.50 per day, and that a convict is only therefore worth 75 cents per day, there does not seem to be any valid reason why he should not be paid in cash the difference between what he has cost the State and this 75 cents, amounting to fifteen or twenty cents per day. This is leaving out of consideration the State's expense for his prosecution, trial, etc.

95.— Places of deposit should be provided for him, in order that his savings, compulsory up to sixty or seventy per cent of the whole, may be paid him upon discharge. Should he have dependents, which is common, the proportion which the prisoner is to send them should be larger, while at the same time he has a greater motive for conscientious work, and is certainly a better man for having the hopelessness of his work tempered by this method.

Even on this basis of 50% efficiency, which is probably far too low, the county is still getting full value for all its funds expended, and there is no trace of charity in the work.

96. Experience with Convicts.— Mr. Coleman, Highway Commissioner of Virginia, advises that prisoners should be divided into four groups, as (*a*) Long term and dangerous men; (*b*) short termers; (*c*) trusties; and (*d*) paroled men.

Class (*a*) includes murderers, men with notoriously bad records, and third offence men. These are to be dressed in

stripes, and worked in stockades or under guard in stone quarries or similar places.

Class (*b*) would include first offence men, and reliable prisoners from class (*a*). These men are to have brown or blue uniforms and work under guard on the roads.

Class (*c*) is made up of trusties from class (*b*). These are to wear ordinary khaki, and work without guards as rollermen, engine-men, cooks and yardmen, and would be sent in small details to do isolated work, as dressing up a stone-road surface, to build and repair culverts, etc., effort being made to have them definitely realize the trust and responsibility reposed in them.

Class (*d*) are those taken from class (*c*) and paroled at some period of their sentence for good behaviour. These men would wear ordinary clothing, and serve in the maintenance department of the State or county as patrols, be furnished with suitable quarters and paid a certain wage, prison control being maintained by a system of monthly reporting to some general head, and otherwise complying with the parol laws of the State. Having thus been carefully trained in road work while a charge of the State, it would certainly be advantageous to the community to have them continue in such honorable and worthy occupation afterward, thus consummating an important step toward the solution of the discharged-prisoner problem. This has also been the experience of other Southern States where the paroled prisoners have subsequently settled down and become respected citizens in the localities where they had previously been stationed. Mr. Tynan, Colorado Warden, has attracted a good deal of attention by his success in working out a parol system, and says the convicts are only "folks" after all. That only one man out of two hundred attempts to escape from the Colorado camps proves to him that the men are willing to do good work and to live up to their agreements if given the chance to do so.

The warden of Sing Sing, in New York, is another profound believer in humanitarian penology, and is prominently committed to the reclamation of the greatest possible amount of human wreckage which comes under his jurisdiction.

98. Custody.— Convict labor is generally used to the best advantage on roads where the grading is heavy, and quarrying is to be done, as it is then possible to concentrate the force so that foremen and guards can give closer attention to individual efforts. Prisoners are of course apt to do as little as possible, on the theory that the labor is their punishment, which they thus to that extent avoid, and are apt to kill a great deal of time making imaginary adjustments to tools and clothing. This of course applies chiefly to those who work under armed guards, and not to those under a parol or honor system.

At night, where a permanent colony is established, as at a quarry, a stockade is usually established, and of course guarded and patrolled. On less permanent jobs, movable living quarters, consisting in substance of long tents with board floors and galvanized iron roofs, with or without bunks for sleeping quarters, are employed, wherein the prisoners are secured to a main chain which is in turn securely fastened to some permanent object.

99. Maintenance Costs.— In 1914 Virginia worked some sixteen hundred convicts on her roads, and found that the average cost per man per 10-hour day was 52.9 cents. She estimates that the convict is about two-thirds as efficient as free labor, but that it is vastly better for the convict, and that most of them prefer road work to confinement. North Carolina reports the expense per man per day as 35 to 55 cents, depending upon wages. It would probably be considerably more in the Southwest and Western United States. Louisiana finds the cost to be 45 to 50 cents per day.

100. Cost of Equipping a Convict Force.— W. E. Atkinson, State Highway Engineer of Louisiana, states that an approximate estimate of the cost of equipping and running a convict camp for road purposes, based upon a force of laborers numbering 50, would be as follows:

Item.	Cost.
10 teams, at $500.00	$5,000.00
10 road slips, at $7.00	70.00
1 road grading machine	200.00
1 road roller	2,000.00
2 road drags, at $20.00	40.00
1 blacksmith outfit	50.00
All necessary axes, picks, shovels, etc.	100.00
Tents for living quarters, dining room, stables, etc.	500.00
Kitchen outfit	50.00
Lumber for cell-house, etc.	500.00
Incidentals	500.00
Total	$9,010.00

A camp of 50 men should be supervised by the following superiors:

1 captain, at $75.00 per month	$ 75.00
3 foremen, at $40.00 per month	120.00
5 guards, at $30.00 per month	150.00
Total	$345.00

CHAPTER V

EARTH ROAD CONSTRUCTION

Methods of attacking the general problem of earth-road improvement are here suggested, and the vast importance of *drainage* in every type of road is emphasized at length. The function of ditches, tiles, and of varying amounts of crown is discussed, with methods for handling the general drainage of the country, especially under unusual conditions, as floods and overflows. Then follows a discussion of the scraping grader, and the tractor, with emphasis on the economy of a good roller consistently and persistently used. There are examples of Standard Road Sections. The fact is emphasized that it pays to do all road work carefully and well, and with considerable regard to appearances. In conclusion, it is shown that like more expensive roads, the main problem of the earth road is one of continued intelligent care and maintenance.

101.— When a new road is to be built, or an old one relocated, the work should always be staked out by an engineer, if possible. Building a road without a survey is almost certain to waste dollars to save pennies.

The engineer locates the line, takes levels, contours, and cross sections, makes a profile, establishes the grades, and stakes out the work. In this way the ditches are sure to be drains and not ponds, the grades will be correct, and the amount of grading will be a minimum for a good road. About $30 to $40 per mile is the usual cost of the engineering services outlined above. If the entire construction can be supervised by an engineer, so much the better, for road-building is an engineer's work the same as raising cotton is a farmer's work, and each is best at his own task.

Method of Attack.— The improvement of our roads should be begun by thoroly building all fills, solidifying the substructure or foundation, lessening steep grades, rounding off hill tops, draining the surface and underdraining ground waters, constructing bridges, and straightening needlessly crooked roads. We should then maintain them as improved earth or

gravel roads, as the case may be, pending the next step of the improvement, the final laying of more costly surfacing, provided that is ever found necessary. All this can be done economically, showing immediate and direct benefits for every dollar spent.

Bad locations should be among the first matters treated, as this imposes a permanent expense, often greater each year than the present cost of correction,— then done once for all. Fortunately, such changes can often be made easily and at slight expense.

102. General.— The principal philosophy underlying earth-road construction consists in underdraining the subsoil where necessary, and then so shaping and maintaining the surface that no water can remain on it. If well built and maintained, the earth road will be fairly good most of the time, and dependable all of the time. If too heavy traffic comes upon it, some stronger and more expensive type of surface is required. Adequate side ditches carry surface water speedily and harmlessly away and a suitable crown to the surface deflects the rain-water to the ditches, preventing the formation of ruts. Water is the natural enemy of all road and street construction and must be kept out of them, off of them, and away from them. With poor drainage even the best roads and streets soon go to pieces. With good drainage a bad road can always be vastly improved. Continued rain and heavy travel will greatly damage *any* road not surfaced with a hard material.

103. Drainage: Surface.—The life of a road chiefly depends upon how the surface water is handled. If the drainage is carelessly treated or neglected it will almost certainly result in the ultimate destruction of the road. Drainage is vitally important with any type of road construction, but on the soft surfaces of an earth road it becomes doubly important. However, it is not a simple question, easily handled, but requires much study.

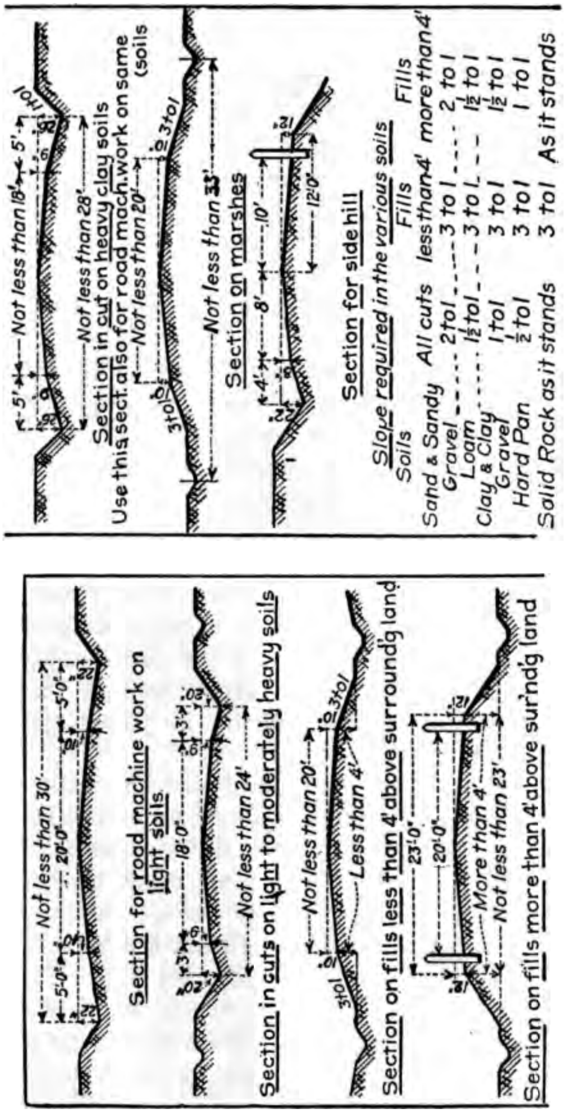
The chief thing is to get the water *away from* the road, and to prevent its entering the road from above, from the sides and from below. Every step in road-building should keep in view *the necessities of drainage.* In this connection, a steam roller

is desirable as it compacts the surface covering, and makes it smooth, hard, and more resistant to the penetration of water. The road should, if possible, slope 1 ft. in 100 ft.

104. Side Ditches or Gutters.— Properly built, side ditches will often drain a damp roadbed, though they primarily care for the water shed from the road surface by the crown. In both ways they play an exceedingly important part and must be looked after at all times, for even when sub-drainage is not needed, side ditches are.

At times it is necessary to carry the water for some distance in the side ditches before it can be disposed of. This may occur in cutting the road through a ridge or hill, leaving a cut bank on each side. In such cases, and especially if the grade is considerable, it is often a good plan to carry the water in tile laid in the ditches, to prevent excessive scouring or cutting. Or it may be a good plan to carry the water for some distance in the ditches and then into the tile by a well or by using a "Y" with the short end or branch turned vertical, with a grating to protect the opening from trash. Where stone is available the same general result can be obtained, probably at less expense, by paving the gutter roughly with cobblestones, or irregular fragments. Another plan builds frequent low cross-walls with weirs, in paved gutters, to slacken the water.

Side gutters must be so constructed that the water reaching them will be carried off quickly, and not stand or seep into the sub-base of the road. Earth slides, drifts of leaves, twigs, or other trash dam the flow. Little attention has commonly been given to this and much water damage has thereby resulted. There will be little seepage from the gutters if properly graded, i.e., if they have sufficient fall. This grade should never be less than six inches to one hundred feet, and one foot is much better. In level country the proper grade is often hard to handle, but the grade of the gutters need not correspond to that of the road. Where it is not possible to give sufficient grade to the roadway, the crown can be increased so that the water will be carried quickly to the gutters, and then sufficient grade given to the gutters to keep the water



—Standard Cross Sections —Grading All Types— WISCONSIN

flowing. This water should then be carried under the road as often as necessary, and to the side where it can be best *disposed of, but it* must never be taken across the surface.

These under-openings, too, must be kept free of trash and rubbish.

105.— *Private entrances* to dwellings and farms offer some obstruction to the side ditch, as a rule. If the gutter can be made very wide and shallow, its obstruction to travel will be lessened. The local owners will often prefer to build a pipe-drain or culvert under their driveway, but it should not become a menace to the road at this point. That is to say, they must be big enuf to carry the water freely; must be set to a true grade agreeing with the bottom of the ditch, so that it will neither dam back the flow nor fill up with mud; they must be strong enuf not to break down with the loads to come upon them; their tops must agree with the top of the road's crown so that travel will not be obstructed over them.

All the foregoing remarks apply with still greater force where we are considering the treatment of drainage structures at road intersections.

106. Secondary Ditches.— When the road is located on a hill-side below a considerable area of watershed, so much water may flow over the edge of the cut into the ditches that those of ordinary size will not hold it. In cases of this kind a secondary ditch, well up on the side of the hill, should be dug. It will intercept most of the water before it reaches the side ditches and save a great deal of expense in keeping up the side slope, as well as protecting the gutter from excessive wash or scour due to the extra flow of water and silt or mud in it. This drain should be of sufficient depth and width to properly dispose of the water and should lead to the nearest drain or watercourse leading away from the road.

107. Sub-drainage: — *Tiles.* A road cannot be maintained in wet ground, but it is seldom that an earth road will have to be continuously underdrained unless its location is entirely in clay. Often there are short sections where the water collects and is retained. It must be disposed of by carrying from the center to either side or from one side to the other and thence away. In such cases it is best to construct porous tile drains. There are many ways of laying them, and all have their advantages. One method will give best results in a

certain case, but the method followed is to be determined by the engineer in charge.

The most-used scheme places the tile directly under the side ditch, or when necessary, under both ditches. A tile drain in a loam or porous section will generally drain a road or area whose width is five times the tile's depth below the surface. Therefore, if the soil is loam, or of similar nature, and the drain is placed three feet under the side ditch, it will drain an area about 15 feet in width, and in some cases up to 20 feet. In a narrow road, where there are ditches on both sides, if the soil is easily drained, one tile will often be enough.

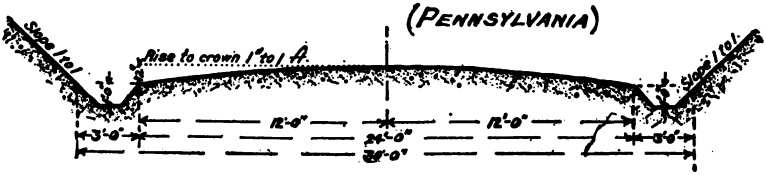
Tile drains keep a stratum of dry soil underneath the gravel or stone placed on the road surface. They are not intended to carry away surface drainage, which must still be carried in open gutters. Their object is to keep water from rising into the roadbed from below. If the soil around them is kept reasonably dry it can then support the gravel or stone covering, and the weight of any traffic that comes over the road.

108. Number of Lines.— For bad sections there are advocates of both one and two drain lines. The safest way is to lay one drain line under the low or wettest side. This line should be deep, and an abundance of rock placed on top of the tile, say to within a foot of the ground surface. Afterward observe its effects carefully. If the entire surface seems to keep dry, and both sides are in a similar condition, this single line is sufficient. If, however, the side opposite the drain remains wet, it is evidence that a line on *that* side is needed. An exception to this rule might arise if the undrained side is bordered by trees, or not much exposed to the sun, or seepage water reaches it. It is commonly held that no tile of less than 5 inches diameter should ever be used.

109. Slope.— Drains should have a minimum fall of three inches in one hundred feet, but one foot in one hundred is much more satisfactory. They must be laid to a true line and slope, otherwise silt pockets will form, clogging the tile. On level ground, the tile may be laid below the bottom of the side ditches. On slopes where the covering over the tile is liable to be washed out, it should be laid under the shoulders

of the road. In addition to the tile, blind drains should be extended diagonally into the center of the road if there are springs or exceptionally wet spots. Ditches for tile should be begun at their lower ends to free themselves of water as the work progresses.

110. Cross Drains.— Cross drains should not be placed at right angles to the gutters, nor placed less than eighteen inches below the top of the sub-grade. They should slope at least one inch to five feet toward the side ditches, and be spaced according to the wetness of the soil. If in very wet clay, holding water, place them every fifteen feet, increasing the distance as the soil becomes drier. Sandy or gravelly soils require spacing from 30 to 80 feet. In some cases, it will be better



SECTION IN EARTH

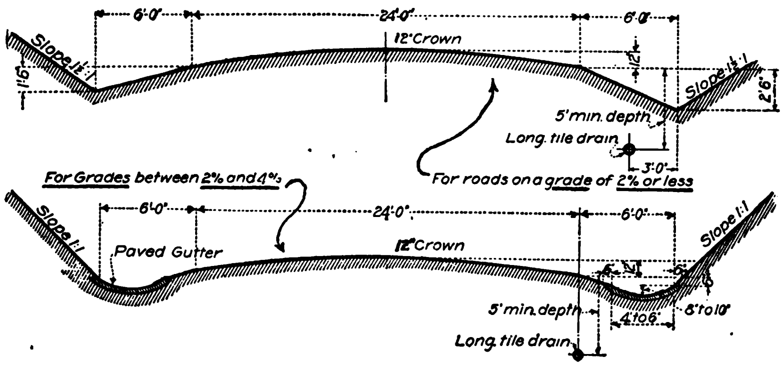
practice to lay a drain in the center of the sub-grade, with laterals running into it, but this should be done only where there is difficulty in disposing of the water from the side ditches, and care must be taken to have the center drain empty freely into the side ditches. Good practice calls for laying these tile all the way from $1\frac{1}{2}$ to 4 ft. in depth. Fifty cents per lineal foot in place is an ordinary cost for tile work.

111. Shape or Crown of Country Roads.— There is no fixed rule regarding the crown of roads, as local conditions and the type of road will necessarily govern. Experience must teach the proper crown to fit them. However, it is most important in new road construction, and in the improvement of existing roads that the problem be carefully considered.

The crown of a road answers the same purpose as the roof of a house. Its purpose is to shed the water. Any means which will compact the loose material on the surface increases its resistance to water. If the crown is too flat water will

collect in slight depressions and traffic soon increases each depression to a good-sized hole. If the crown is sufficient to promptly drain the water falling on it to the side ditches the road surface will be kept comparatively dry. But a strip of sod or weeds allowed to grow between the traveled way and the ditches practically defeats the purpose of the crown.

112. Amount of Crown.— The amount of crown depends on the width of roadway, the grade of the road, and the character of the soil of which the road is built. If the slope along a rut is greater than that to the gutter and the soil washes



CUTS —— Cross Sections for Earth Roads.

easily, disaster will follow. Only sufficient crown should be given to a road to do what is required of it. Do not make the crown so great that the center will be the only part of the road safe for traffic. If crowned too much the most traffic will use the center, where it is nearly level, and maintenance work will be heavy. A flatter or proper crown will permit an even distribution of the load on all four wheels, while if too great, there will be a greater load thrown on the two lower wheels and the cutting will be greater than on the upper wheels.

Some experts claim that roads when completely consolidated should have a minimum crown of one inch to the foot. That is, from shoulder to center, a roadway 24 feet between gutters should have a crown of 12 inches above the shoulders. This crown is for a fully consolidated road, not for a new gravel

or stone road on which the stone or road material is left without rolling. A new road even when consolidated should be too high to commence with, otherwise it will soon get too flat. Every tendency of wear and of the forces of nature is to flatten the roadway. It will therefore soon hold water if not given an excessive crown in the first place.

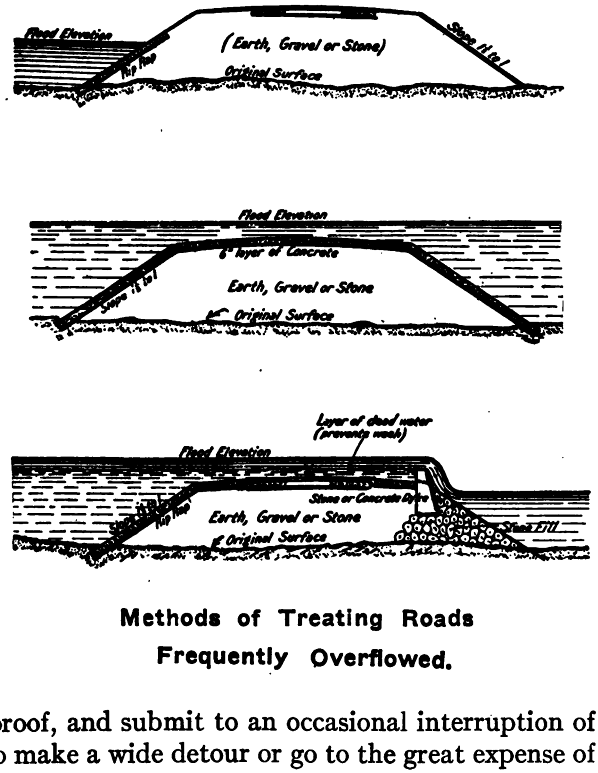
Straight-sided Crown.— Where the sides of the crown are sloping straight lines, as some contend for, the sides of the road soon wear hollow and hold water that should flow to the gutters. These hollows containing water soon form holes which increase in size. But if traffic is greatest at the center of the road, as is usually the case, the action of the horses over it will soon wear it to about the same crown curvature as is generally conceded to be proper shape.

113. Country Drainage.—The proper disposal of water which falls upon a road surface, or finds its way into the subsoil where the road lies, is by no means the end of the road-builder's problem. There still remains to be handled the drainage of the country through which the road passes. "Every hill has its hollow," and every valley has its stream at least when it rains, and our roads must by bridges and culverts be safely and economically carried across them. To cover this subject calls for more advanced engineering than this course can afford, yet we can at least consider the principles upon which sound and economical design must rest.

The engineer should investigate all the streams, learn something regarding their sources, and take measurements of them at or near where they will pass under or parallel with the road. He should know how rapidly they rise in cases of sudden and heavy rains, whether they overflow their banks and to what extent, as well as how and where the overflow goes in such cases. He will then be able to intelligently design the gutters, determine sizes of culverts and bridges, and to know where these should be located.

114. Country Drainage: — *Exceptional Conditions.* When the road crosses a stream of some magnitude having a wide valley subject to floods and inundations, as is not uncommon in Oklahoma, special difficulties enter the drainage problems.

Where the ground is level and subject to flood mainly by back water, an extra number of small cross drains or culverts will usually accomplish the desired result. It may, however, cost a good deal to raise the grade of the road above flood level or to control the flood level by channel improvements. It will probably be cheaper to build a road at a lower level, make it



Methods of Treating Roads Frequently Overflowed.

flood-proof, and submit to an occasional interruption of traffic, than to make a wide detour or go to the great expense of a large fill or viaduct. But if the ground is subject to floods running at high velocity — a condition which arises where roads cross wide level valleys of a considerable stream subject to severe floods — great care is necessary. It may be best to allow the flood water to overflow the road at some points, which must then be made flood-proof, by paving, rip-rap, or low masonry walls. Where such overflow points are provided, they should

be made long and shallow to reduce as much as possible the velocity of the current flowing over them, and be so located as to reduce the actual damage to adjacant property to the minimum. (See drawings.)

If the proposed road crosses a narrow valley with a rapid stream, it is nearly always best to give the bridge ample waterway and fix the grade above the reach of high water, taking care to protect all exposed points against erosion. It is better to cross valleys if possible where they are narrow and the streams rapid. Such conditions reduce the amount of embankment required and also the span of the bridge.

115. Surface Betterment.— When new material is spread upon an earth road, care should be taken to secure it from the best available supply, similar to that already in place. Thus, it is not good practice to place gravel in patches upon an earth road to fill hollows. Material should be spread uniformly upon the traveled way, and should be applied for a considerable distance, with the ends of the layer tapered off gradually to prevent a new chuck-hole. The scraping grader is widely used for surface improvements. It is designed to simultaneously construct gutters or side-drains and place material for the crown in the center. The machine, and its use, is, however, too well-known to warrant an extended description here.

116. Construction by Grader.— In building a new road with scraping grader, the blade should plow a furrow about six inches deep on the outside line of the ditch, using the point only. This should preferably be done on both sides of the road. On the second cut, the outside wheels, front and rear, should nearly track and the furrow should be the full width of the blade, guiding it by the first one cut. On this cut, the rear of the blade should be lowered and adjusted so that the material taken out will be spread toward the center of the road.

On the third cut, the grader should be moved toward the center of the road so that it will take up the material that has been cut on the last round, spreading it over near the center. If the cut is as deep as necessary, the rear of the grader should be elevated so as to let some of the earth distribute under it, to give the side the proper crown before filling up and com-

uniformity in laying out and building work when thereby simplicity of construction is furthered, the work of designing reduced, and greater efficiency and better workmanship secured. The first step in the preparation of any design consists in defining limits of cost, capacity, foundation conditions, materials, and construction plant requirements. For each combination of conditions there is perhaps one best plan. If the combination is frequently met a standard design leads to economy, and one should be prepared and used.

This text presents numerous Standard Sections and designs in the spirit of the foregoing discussion.

121. Value of Good Appearance.— It should be the effort of every one connected with earth-road construction to get and maintain the road to true line, grade, and cross-section establisht by standard plans in cuts, fills, and on level stretches. Of course this gives a true and finished appearance, gratifying to those who have helped make it, but that is the least of the advantages secured.

In the first place, the full width is available for use, with the result that travel has an opportunity to distribute itself over the whole crown, thus avoiding cutting it into bad ruts by continually using the same track. This reduces the cost of upkeep and maintenance.

In the second place, it increases the safety of travel, especially in wet weather, as the crown is evenly and not too abruptly sloped, and there is no narrow and impassable ridge in the center.

In the third place, keeping the shoulder line straight makes it possible to make and keep a straight gutter with a true bottom grade, while it is practically impossible to make the gutter-bottom true and evenly sloped if its top is crooked and winding. If the bottom is not true, but is full of pockets and holes, water will necessarily stand in them, tending to soften and damage the sub-grade.

In cuts, shaping the back-slope carefully is wise and economical, besides greatly affecting the appearance of the job, while the remarks just made about gutters apply here no less, *also. If a ragged, steep,* turfy bank or slope hangs above the

Showing results of deficient waterway under small bridge.

gutter it will be only a short time until the loose material will wash down into the ditches, when it must either be removed, or, being left, will cause the water to damage the road surface either by erosion, or will soften it by standing in pools in the clogged gutters. The easiest time to care for this is while the cut is being made. It is especially desirable to make the back-slope as flat as possible, particularly in cuts of moderate depth, so that if possible the weeds certain to grow there can be mowed with a machine. A slope of one foot rise to two horizontal is regarded as a good practical minimum to work to. If these weeds are kept cut, it greatly assists the slope to come into sod, and when once in grass this will largely prevent washing down into the ditches, and so greatly lessen the maintenance cost of cuts.

In this connection, the road-builder will always be repaid by assuring himself that his ditches are of ample width and capacity. A depth of 2½ ft. is not too much, but the back slope should be easy, and the inner slope less than 45 degrees with the horizontal. In cuts, the ditches should not be simply discharged at the edge of fresh fills, where they are certain to do a good deal of damage, but should be carried around on the hill-side in an independent ditch cut in sound and undisturbed earth, discharging as far away from the fill as circumstances will permit.

The task of smoothing-up a new fill, especially if most of the care in distributing the material is put off until the fill is practically completed, is by no means an easy one. There can be no doubt that care in placing the material fully out to the proper slope lines as the fill progresses, keeping the surface as level as circumstances will permit, working it out into layers and applying all available means for compacting the fresh material,— all of this care will be amply repaid in the better job secured.

121A. Conclusions.— The earth-road problem today is largely a problem of repair and maintenance. No earth road will endure travel without constant care. The split-log drag, or "Road-Planer," or steel scraping-drags furnish the best method for preserving road surfaces and establishing proper

surface drainage from the traveled way to the side ditches. Earth road repairs become unnecessary in proportion to the increased care in road maintenance. It cannot, however, be expected to start any maintenance upon an earth road until it is put into reasonable repair. The repair should follow the lines indicated above, that is to say, earth-road repair should include some permanent drainage work, the reduction of some of the worst grades, the straightening and widening of bad curves and bettering the road surface by removing worn-out and objectionable material.

CHAPTER VI

COST ACCOUNTING AND EARTH-WORK

When a construction job develops beyond the simplest type an increasing number of elements enter in to affect its cost. When clearly recognized, we may then begin to keep track of them, and if found too high, steps taken for lessening excessive ones. Plainly a classification of cost elements is the first step, whether the work is actually going on, or is being planned for the future.

Cost systems aim to find how to get the biggest possible value for every dollar spent. In handling earth for building roads, this aim, tho frequently entirely neglected, is yet of vital importance. Hence the inclusion of the following discussion here.

The elements of managerial efficiency are suggested, cost analyses of the different kinds of road work are outlined, and subjects for further studies indicated. A few illustrative road costs are given. And since cost discussions are pointless without knowledge of the *quantities* handled, approximate methods of arriving at earth-work volumes are shown.

122. GENERAL.— In construction work money is most commonly misspent and wasted because:

a. Those in charge do not know how much the work *is* costing; or

b. They do not know how much it *ought* to cost under the given conditions.

While one job may be done much cheaper than a similar one elsewhere, the reasons for this difference may not readily appear. It will usually be found that the difference is due to a variety of factors, not to any single one, and considerable skill in analysis may be required to discover which item is chiefly responsible for the excessive cost.

The science of cost analysis consists in discussing the whole after it has been cut into the greatest practicable number of independent parts, or items, and then giving each of them scrutiny and extended observation to see whether it cannot be reduced to still lower terms, and lesser cost totals. Thus the *object* of COST ACCOUNTING is to secure knowledge

essential to the effective and economical control of maintenance forces and of construction work. To accomplish this it is necessary to establish a suitable system of cost records and directions for procedure. Field and office conditions must be anticipated as fully as possible and definite instructions governing use of forms and methods of conducting work should be issued in permanent form for the education of employees.

122A. General Objects of Cost System.—These objects are:

1. To ascertain the total and unit-costs of each class of work performed, for the purpose of daily checking, and for future estimating.

2. To show the quantity and cost of each class of work performed within the boundaries of any road division and for any separate road-unit or organization.

3. To show separately the three main elements of expense entering into the cost of each class of work as follows: (*a*) Labor charges; (*b*) material charges; (*c*) plant and equipment charges.

4. To show in a comparative way the cost of performance of each unit, gang of workmen, plant for producing material, etc.

5. To secure by interpretation of these data knowledge as to the efficiency of performance of any road or other forces, thus facilitating administrative control; in short, to prevent "soldiering."

6. To show, when taken in conjunction with current conditions, whether, in service, the public is getting value received for the money spent.

7. To permit a determination of the point beyond which it will be undesirable, from an economic point of view, to continue maintenance work on existing roads, or to tell when replacement of road surfaces, or of machinery, or of tools in use, or changes in general methods of doing work, must be contemplated.

8. To get such data so promptly that defects in management may be detected and remedied before the money is gone, i.e., to avoid *present* leaks,—*post mortem* examinations are of *little effect.*

Showing that it pays to take pains to finish the job up smoothly. See § 121.

The split-log drag — everybody's roadbuilder.

123. Value of Earth-work Costs.— Why should the road-builder care what earth-work costs, and what is meant by this phrase? By "earth-work" is meant the digging away and cutting down of the earth, gravel, or stone on the hilltops and moving it down to the low places, thereby improving the grades, and increasing the loads which may be hauled over the road. Past experience shows that untrained road-builders are usually unable to intelligently estimate what a given grading operation will cost. Frequently they have arrived at the end of the available money, long before the job is done, sometimes with the undertaking scarcely more than well begun. As the part done was planned to fit work which was *not* done, the public is more likely to suffer inconvenience than benefit by the attempt to improve. Perhaps completion requires a much greater sum than is economically justified. That is to say, with $800 such a man would undertake to do a $3500 job, and of course miserably fail, — to the great detriment of the traveling public and waste of the tax-payers' money.

124.— Likewise, where the work is not heavy but consists of relatively small quantities of material over considerable areas, among untrained workers not fully posted as to what such work *is* costing, or *should* cost, the tendency is to waste a great deal of money. Is it then difficult to estimate roughly at least what earth-work should cost? No! We will consider the leading factors entering into earth-work costs and show how the quantities involved can be roughly approximated. But before doing so let us consider briefly the managerial elements, or a few points requisite to the successful handling of gangs of men if a maximum output for the wages is to be obtained. This does not suggest that men should be rushed, or crowded, or in any way abused, but means that if they are intelligently directed they will accomplish much more and with less effort then if they are not. We quote in part from the foremost authority: Gillette's "Cost Data:"

125. "Co-ordination.— Observation of almost any piece of construction work in progress will show that most of the men spend considerable time waiting either for somebody else to do something, or for materials to arrive before they can pro-

ceed. The cause is *improper co-ordination* of the work. In a sequence of operations one gang may have too many men and working considerably faster than another, is continually catching up with it. They will then adopt a slower pace, keep seemingly busy, and manage to kill a large percentage of their working time. These delays are chargeable to lack of co-ordination, although a careless inspection of the work may seem to indicate that everything is going smoothly. A job can look smooth and at the same time be so badly co-ordinated as to be uneconomical."

To illustrate, the following is extracted from a State Engineer's Report:

"A complete record of all concrete culvert work was kept, which shows clearly where the contractor's losses occurred, as follows:

Constant delay on account of lack of material, sand and gravel, and sometimes lumber, was a never-ending source of trouble. The cost of concrete culvert and head walls was excessive for various reasons, namely:

High cost of sand and gravel.

Long team hauls over rough roads.

Wagons loaded lightly and *teams* working *under time*.

Inefficient foremen and *men* allowed to work *under time*.

Long haul for water in some cases.

Too many men in some cases, excavating, concreting, etc., getting in each other's way.

Common labor, with poor tools, used on forms, instead of carpenters.

Lack of organization."

126. Reward Increasing with Increased Performance.— Pay should be proportionate to the work done. This is the fundamental law of economical production. When ignored—and it is partly ignored on practically every class of work—the producer ceases to take keen interest in his work. Under the common wage system of payment, one brick mason receives as much as another, regardless of skill and energy. Individual incentive is lacking, save as it is supplied by fear of discharge. When laborers, working under the ordinary wage system, are put at the task of shoveling earth into a wagon, each man seeks to do as little as his neighbor, and the slowest becomes the pacemaker for the rest. Such ambition as any individual may possess is stifled by the knowledge that his increased output will never be known by his employer, and consequently

never rewarded. Moreover, an ambitious man in such a gang is chided by his fellows who warn him not to set a "bad example" by working himself out of a job.

127. Gang Efficiency.— Where the construction work on public roads in a county or district is sufficient to extend over a series of years, it is possible to get squads of roadmen trained so that they become very efficient and considerable rivalry is often aroused between them both as to the amount of road they can construct within a given time and the quality of the work done. The foremen often become interested in this rivalry, and the result is a more personal interest of the foremen and roadmen in the work that they are doing. A system of special rewards for meritorious work can here be used to great advantage.

128. Executive Results of Cost Keeping.— As showing more in detail what may be expected from an adequate system of cost records, the following is quoted, in part, from Gillette and Dana's " Cost Keeping and Management Engineering." It is merely another summary of general principles.

" The two primary objects of cost keeping are:

(*a*) To permit an analysis of unit-costs which will lead to securing the minimum cost possible of attainment under existing conditions.

(*b*) To provide data upon which to base estimates of the probable cost of projected work.

Probably the former aim is the most vital one, unless contract-work is specially under consideration. However it is to be accomplished, the system of analysis should provide a way of knowing whether a job is costing more than it should or not. This should be emphasized, for in no other way can we tell if money is being wasted. And this applies equally to all sorts of jobs, even to the simplest.

As a result of analyzing unit-costs, and comparing them with corresponding costs of similar work previously done, a manager or executive may discover such things as the following:

1. Excessive use of materials in erecting a given structure.

2. Excessive use of supplies (coal, oil, gas, waste, etc.,) in operating a plant or machine, say a traction engine, suggest-

ing whether this excess is due to ignorance, carelessness, or theft.

3. Inefficiency of workmen.
4. Inefficiency of foremen.
5. Padded payrolls.
6. Excessive loss of time, due to: (*a*) plant breakdowns; (*b*) plant shifting; (*c*) waiting for materials or supplies, etc.
7. Improper design or arrangement of plant, etc.

Cost keeping also leads to the introduction of piece-rate or bonus systems of payment, which may in fact be said to be one of the ultimate objects of cost keeping. Systematic analyses and study of costs leads inevitably to a study of the reasons for differences in them, which in turn, is the first step toward inventing new machines and methods for reducing costs. Cost keeping should generally require daily reports by which a superintendent can gauge the daily performance of his organization, thus permitting him to discover inefficiency promptly."

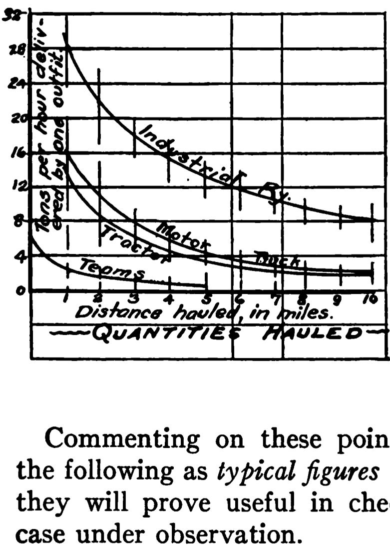
129. Beginning Cost Records.— When cost keeping is begun, it is well to start in a small way, taking some particular kind of work, like teaming, to say concrete-mixing, or the mileage done by a grader, etc., and applying a system of daily reports to it. When this branch of work has been analyzed and put upon a satisfactory basis, some other feature may be taken up, thus developing a cost system gradually and effectively without disorganization. Such cost keeping records should carefully state *conditions*, such as weather, distance hauled, facilities for loading and unloading, unavoidable waits, etc., and whether the figures are for the beginning or ending of the job. All of these, and similar details, are essential to a correct interpretation of results.

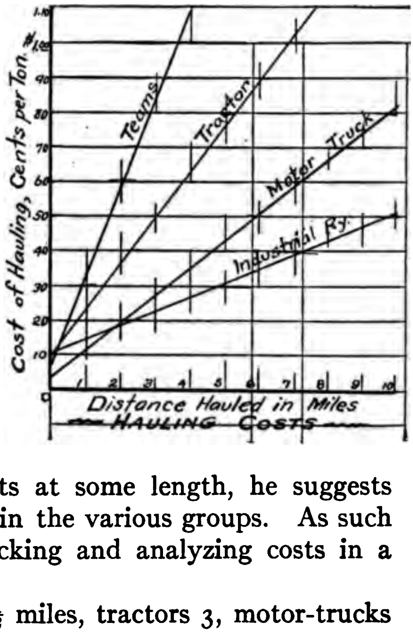
129A. Hauling Costs:—*Example of Analysis.*—Builders of roads and pavements have long realized that a very large item of cost is incurred in hauling materials. There are numerous elements affecting this cost, and these will vary widely with conditions and localities. With suitable records, however, it is possible to make a reasonably correct allowance for them, and so arrive at a fair estimate in advance upon which, for

example, intelligent judgment whether to accept or reject bids may be based.

Thus Mr. T. R. Agg, a painstaking observer prominent in Iowa road work, points out that the cost of hauling varies with the following factors:

1. Length of haul.
2. Rate of travel of outfit used.
3. Amount of time lost loading and unloading.
4. Time lost on account of bad roads.
5. Capacity of outfit per trip.
6. Cost of operating the outfit.





Commenting on these points at some length, he suggests the following as *typical figures* in the various groups. As such they will prove useful in checking and analyzing costs in a case under observation.

Under (2), teams average 2½ miles, tractors 3, motor-trucks and industrial railways, 10 miles per hour, returning empty in each case.

Under (3), hand-loading takes longest, and bins or similar special devices are essential as the plant becomes more expensive. Teams average a loss of 18 minutes, motor-trucks, loaded from bins, 6 minutes, and traction outfits or railways, 30 minutes.

Under (5), teams haul about 2 tons, motor-trucks 5, tractors 15, and railway 20 tons each per trip. With this it has been found that a fair figure of costs of operation are for: Teams, 50 cents per hour; motor-truck, $2; tractor outfit, $3; and railway, $4 per hour.

As has just been said, the cost of hauling is made up of all of these items, in many possible combinations. The diagram herewith is probably a fair indication of their combined value under average conditions. It especially indicates the economic limits of hauling-distance imposed upon each type of equipment. A contractor could not safely base his bids upon the costs shown, but should prepare a similar figure for himself. A road-official, however, could use it as a means of intelligent checking in cases arising under his jurisdiction. Note that the first figure compares the cost of hauling, while the second compares the amounts delivered at different distances. Mr. Agg is careful to point out, however, that the factor of superintendence or managerial efficiency is not and cannot be shown on these curves. A good man will doubtless make a substantially better showing than this; the performance of a poor one would probably fall considerably below with resulting increase of costs.

130. Auto-trucking.— A recent instance in Maryland gave a cost of $8\frac{1}{3}$ cents per ton-mile for hauling crushed stone, or 33 cents for four miles, with auto-trucks. A fair estimate for teams to do the same work would be 70 cents, or more. But this contractor ran five trucks continuously thru the 24 hours. This is the most favorable condition for economy with this type of equipment, since in this case the interest and depreciation costs on the plant in use was about $16 per day, whether used or not. It is, however, very easy to underestimate the cost of motor-trucking, with consequent disappointment when actual costs are counted up.

Economy in Lighter Equipment. — When planning to do power-hauling the relation of the proposed loads to the roads over which the hauling is to be done must be taken into account. While in theory the larger the carrier and the heavier its load the cheaper will be the unit-cost per ton of material moved, in practice the load will be limited by the character of the road. If loads are too great, enormous maintenance charges will be required to keep the roads passable. In other words the loaded units must frequently be smaller and lighter than would otherwise appear to be necessary to have them.

Motor-Trucking and Road Surfaces.— The relation of motor-trucking to ordinary road surfaces is constantly requiring study and attention, especially where general freighting is done. The rapidly moving pleasure auto having large round pneumatic tires, which flatten slightly when in contact with the road surface, has been observed to have a scrubbing or scouring action, stripping the surface, but not disturbing the bottom layers of the road surface until the top layers have been removed.

On the other hand, the motor-truck, when it has common solid rubber tires, often approaching in shape a blunt wedge, drives them into the road by its great concentration of load, often as much as two tons per wheel. These have a very different effect. Such tires have been observed to exert a powerful shearing, or downward-cutting action upon the road-crust, soon penetrating clear thru it and deep into the subgrade. The road-crust must therefore have great strength and be able to withstand this very destructive action, distributing it over a sufficient soil-area. A concrete base under some form of block pavement, as brick, wood, or stone, or in a pavement entirely of concrete, performs just this function. By the same reasoning, the early destruction under such traffic of improved earth, gravel, or macadam roads is certain. It is clear, therefore, that to build any of these inferior types where it is known in advance that an appreciable amount of such traffic will come upon it is a plain waste of public money, for none other than the strong and expensive pavements mentioned can hope to successfully withstand it.

131. Estimating Quantities. — *Illustration.* Take for example a cut in the top of a hill. How many cubic yards in a section 25 ft. long when the cut is 12 ft. deep, and the roadbed is 24 ft. wide. We will consider that the sides of the cut are sloping out at an angle of 45°, or as the engineer says "one to one," meaning that the slope falls back horizontally one foot for every foot of rise. If we now think of a cross-section at one end of our 25 ft. section, we shall see that its central portion is a rectangle 24 ft. wide and 12 ft. high, containing 288 sq. ft. To the right and left of this section will be the area representing the material taken out to make the side-slopes. It will be seen that the tops of the slopes, that is, the points farthest from the center, are where the original surface is cut, and will be 12 ft. away from a point over the gutter, or foot of the slope, and the same point is 24 ft. away from the center-line of the road. In the cross-section, therefore, there is a triangle which lies by the side of the rectangle first considered, which triangle is 12 ft. wide and 12 ft. high. As the area of a triangle is one-half the product of its base by the altitude, the area of this triangle is 6 x 12, or 72 sq. ft. If this represents the side-slope material on the left of the road, there

is the same on the right, so another 72 sq. ft. must be added, giving a total of 432 sq. ft. as the total area of the cross-section at the point selected.

This computation has assumed that on both sides of the road the original ground surface is level. Now as we move along the road 25 ft. we shall find another cross-section exactly like the one just described and of equal area, that is 432 sq. ft. Engineers use for the volume of such a solid the "Average-end-area method," meaning that one-half the sum of the two end areas is multiplied by the distance between them measured along the road. Since we have assumed that the road is level for 25 ft., the volume will be obtained by taking 432 ft. (the average-end-area) times 25 ft. (length of the solid), giving 10,800 cu. ft. Dividing by 27 (cu. ft. in a cu. yd.) gives exactly 400 cu. yds. as the volume of earth in our 25 ft. section. If therefore it would cost 50 cts. per yard to move this material, $200 would be needed for the job, or as it happens $8 per running foot. It is plain also that if by careful management this cost could be reduced to 30 cts. per cu. yd., a considerable saving would result. This is about the simplest possible case and we will next consider one whose elements are not quite so simple.

131A. Non-level Cross-section.— Suppose a road requires a cut of nine feet on the side of a hill. The roadbed is to be 22 ft. wide, the side-slopes are $1\frac{1}{2}:1$, i.e. for each one and a half foot horizontally the rise is one foot vertically. The hill-side, in this case, is not level across the road, but slopes downward to the left at the rate of 2 ft. for each 11. Hence the cut at the left gutter is 7 ft.; at the center, 9 ft.; and on the right gutter 11 ft. It takes a working knowledge of higher mathematics (whose explanation will not be attempted here, to find by computation where the side-slopes of the road run out, or cut the original surface of the ground. The engineer finds where the slope-stakes should be set by trial with his instruments on the ground (a relatively simple matter) but we must have recourse to still another method here, viz.: that of *plotting* the desired cross-section of the road. One easy way uses "cross-section paper" which is ruled into little squares, *say of* $\frac{1}{8}''$ sides, and each square is taken to represent a foot, by

its sides, hence a square foot by its area. Hence if upon such paper the various dimensions and slopes of the road cross-sections are laid off, or plotted, then the number of squares, or fractional parts included within the boundaries of the section, represent the required area in square feet of the cross-section.

This process must be repeated at every cross-section whose area is desired, and then the average-end-area method of getting the volume applied as just explained.

Still another method, similar to the last, uses plain paper to plot the cross-section on, but lays the work off to some lineal scale, as $\frac{1}{8}'' = 1$ ft. with the angles and slopes as noted. In this case the needed dimensions of the triangles required can be scaled in the same units, and the area found as before.

Applying this method to the case just put, it is found that the up-hill slope-stake is 32 ft. from the center-line, while the down-hill stake is only 17 ft. from the center. Similarly the area of the left triangle is about 27 sq. ft., of the central part, 198 sq. ft., and the right triangle 126 sq. ft., making a total area of 351 sq. ft. for this section.

Of course many more complicated features are met in practice than those described, and the engineer also has other methods of dealing with them, but enuf has been shown to enable one, otherwise inexperienced, to calculate the volume of earth-work in an ordinary cut with considerable certainty and accuracy.

In cases where the cut ranges from a few inches to a foot, where the work is done for example with a scraping grader, it is practically impossible to compute the exact yardage,—in fact it is hardly ever desirable to do so. As suggested elsewhere, however, costs are almost certain to creep upward unless checked against quantities of work done. Hence in such cases, also, fairly close estimates of earth-work can be made by the methods shown, and valuable figures for comparison be obtained.

132. Cost of Excavation (Arts. 132–7 based on Gillette): —*Kinds of Earth.*— Earth may be divided into three classes as regards difficulty of excavation: (1) Easy earth; (2) average earth; and (3) tough earth. To the first class belong

loam, sand, and ordinary travel, which require little or no picking to loosen ready for shoveling. To the second class belong sands and gravels impregnated with an amount of clay or loam that binds the particles together, making it necessary to use a pick or plow drawn by two horses to loosen the earth before shoveling. To the third class belong the compact clays, the hardened crusts of old roads, and all earths so hard that one team of horses can pull a plow thru the earth only with greatest difficulty, but that two teams of horses on one plow can loosen with comparative ease.

Work of Teams.— The loads that a two-horse team can haul (in addition to the weight of the wagon) over different kinds of roads are as follows:

	Short tons.	Earth, cu. yds.
Very poor earth road	1.0	0.8
Poor earth road	1.25	1.0
Good hard earth road	2.00	1.6
Good clean macadam road	3.00	2.4

133. Cost of Plowing.— A team on a plow will loosen 500 cu. yds. of loam, or 350 cu. yds. of loamy gravel, or 250 cu. yds. of fairly tough clay, per 10-hr. day. For "average earth," therefore, assume 350 cu. yds. per day loosened by a team and driver and one man holding plow. With wages at $3.50 for team and driver, and $1.50 for laborer, the cost of plowing average earth is 1½ cts. per cu. yd.

In plowing very tough material with a pick-pointed plow, four horses and three men, estimate 180 cu. yds., plowed per day at cost of 5 cts. per cu. yd.

Cost of Picking and Shoveling.— The cost of loosening with a pick and shoveling into wagons is as follows, wages being 25 cts. per hour:

	Per cu. yd.
Easy earth, light sand or loam	20 cts.
Average earth	25 "
Tough clay	33 "
Hardpan	66⅔ "

The amount of earth that a man can load with a shovel varies with the character of the earth, the way it has been loosened,

the size and shape of the shovel, etc. If a man is shoveling earth from the face of a cut that has been undermined and broken down with a pick, he can readily load 18 cu. yds. per 10-hr. day, after the earth has been loosened. If he is shoveling plowed earth, where he must use more force in driving the shovel into the soil, he will easily load 14 cu. yds. of average earth in 10 hrs. If he is shoveling loose earth off boards upon which it has been dumped, he can load 25 cu. yds in 10 hrs., but it is not wise to count on more than 20 cu. yds. even under good foremanship.

134. Cost of Trimming, Rolling, etc.— After earth has been dumped from carts or wagons, a man will spread in 6 in. layers by hand 75 cu. yds. in 10 hrs. at a cost of 3½ cents per cu. yd. A leveling scraper, or road machine, will spread large quantities of earth for 1 ct. per cu. yd. With leveling scraper operated by a team and driver and a helper, 500 cu. yds. may be spread per day. A road machine, operated by 6 horses and 2 men, will spread 900 cu. yds. in 10 hrs. in 6 in. layers, earth having been dumped from patent dump-wagons. Embankments can be consolidated with horse-drawn rollers for ½ to 1 ct. per cu. yd., wages of a team being $3.50 a day.

135. Cost by One-horse Carts.— If the wages of a horse are $1 per 10-hr. day, and the wages of a driver are $2.00 a day:

RULE: To fixed cost of 22 cts. per cu. yd. add ¾ ct. per cu. yd. per 100 ft. of haul.

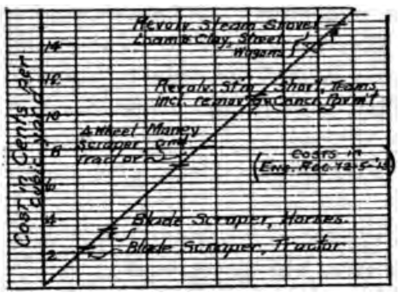
If the material is plowed, and is shoveled easily, the fixed cost may become 15½ cts. per cu. yd. instead of 22 cts.

Cost by Wagons.—If we assume this cost to average 16 cts. per cu. yd., where the earth is plowed, and add 6 cts. for lost team-time and dumping, we have a fixed cost of 22 cts. per cu. yd. Then the cost of hauling will depend upon the size of the load, and, assuming wages of team at 35 cts. per hr. and speed of travel 2½ miles an hour while actually walking, we have the following rule:

RULE: To a fixed cost of 22 cts. per cu. yd. add ½ ct. per cu. yd. per 100 ft. haul when the wagon load is 1 cu. yd.

136. Cost by Wheel and Drag Scrapers.— Cost by wheel scrapers varies according to the size of the bowl of the scraper,

but should be about 10 cts. per cu. yd. for 100 ft. "lead" and say 3 cts. for each additional 100 ft. hauled.



EARTH-HANDLING METHODS COMPARED

If the average load of a *drag scraper* is $\frac{1}{7}$ cu. yd., hauled at a speed of 220 ft. per min., the cost of hauling is $4\frac{1}{2}$ cts. per cu. yd. per 100 ft. of "lead." Note that this "lead" is measured on a straight line from the center of pit to center of dump. The rule, then, is as follows for "Average earth" when team wages are 35 cts. per hr.:

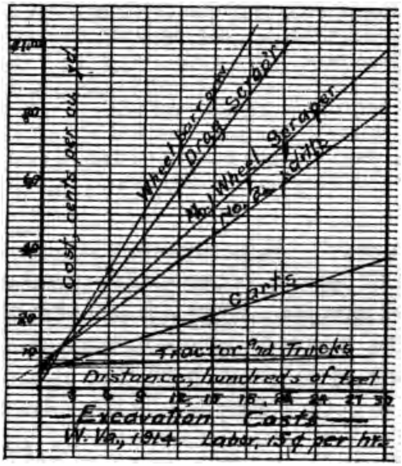
RULE: To a fixed cost of 9 cts. per cu. yd. add $4\frac{1}{2}$ cts. per cu. yd. per 100 ft. of "lead."

137. Loading Methods.— The use of steam shovels has thus far been limited on road work. In general, they require a large investment, use skilled labor, and have a heavy overhead expense covering installation, moving, etc. They are well adapted to very heavy work, and might be economical for loading very large quantities of material at one place. The cost of moving and operating the large machines precludes their use on road work, but of late several manufacturers have given special attention to a light and very portable machine running on its own power, on wide traction-engine wheels, and designed especially for road work. These machines are economical, it is claimed, for very light cuts, even as low as one foot of depth, particularly those machines possessing a horizontal crowding-motion on the dipper.

For loading earth from a road surface, the elevating grader is most economical, particularly on long hauls where dump-wagons are available. A less pretentious, but still effective device consists of a skidway up which scrapers can be drawn and dumped into wagons, or a platform with trap-door under which the wagons stand to receive scraper-loads. Where there is any considerable amount of hauling to be done, careful

study should be given to the loading methods, as observation shows there is often great loss of time and expense at this point.

Loading-bins with belt or other conveyor devices have been very successful in large gravel-handling jobs, and when it is screened in the operation a uniform material is furnished which, tho costing a little more, may well be worth the extra expense in its possibilities of better road construction.



138. Minnesota Road Costs.— Following are total amounts and costs of certain classes of work done under supervision of the Road Department during 1914.

					Average
Clearing and grubbing	3694.90	acres..........	cost	$ 197,312.01	$ 53.00
Ditching	409.98	miles..........	"	194,696.14	474.13
Grading	2150.87	"	"	1,478,826.56	687.50
Graveling	537.43	"	"	366,892.73	682.40
Macadam	29.5	"	"	83,988.60	2,847.00

On state roads and culvert work Minnesota has the following amounts reported:

Clearing and grubbing	912.50	acres..........	cost	$ 45,083.20	$ 50.00
Grading	637.47	miles..........	"	792,394.51	1,243.00
Turnpiking	466.53	"	"	110,114.80	236.71
Graveling	276.46	"	"	229,945.19	1,089.20
Sand-clay	14.07	"	"	10,658.52	4,009.80

CHAPTER VII

EARTH ROAD MAINTENANCE

The secret of good roads at little cost is chiefly one of maintenance. It must be continuous, intelligent, and systematically planned and administered. To secure good results over a large area, there must be an effective centralized organization for maintenance, no less than for construction. Specialists in maintenance are needed. The theory, practice, and limitations of road dragging are discussed at length with a summary of experience in the use of this modern method of maintaining the dirt road. This outlines the content of this chapter.

139. Maintenance.— Who erects an expensive building and does not expect to paint it occasionally, mend its roof, or make occasional minor repairs? Even if it is a cheap structure, must we not expect to repair or renew it occasionally? And such repairs and renewals will cost more than if a more substantial and expensive structure was first built. Then why expect a roadway or pavement, of any type or cost, to take care of itself? With highway traffic yearly increasing, experience plainly shows that maintenance should begin from the day of first completion of the road. " A stitch in time saves nine,—" It's cheaper, too.

The construction of any kind of a road presupposes establishing a repair and maintenance fund. The public and road-officials in this country have often been sadly neglectful of the calls of existing roads for renewals and upkeep. Neglect of repairing the cheaper forms of road construction has done much to discredit them with the public, and has frequently led to a clamor for high-class and costly pavements not warranted by the facts. As it often leads to the construction of a more costly pavement than the situation justifies, this imposes an unnecessary burden on the tax-paying public. It also leads to a great curtailment of the mileage constructed and in the number of people benefited by the improvement.

140. Justifying Expenditure.— The real question is, must we spend as much as we think to get something that will serve adequately? In road work there is always some other method or material almost as good, or a little less expensive than the one we have in mind, or would like to adopt. Usually a low-cost road well-maintained is much cheaper than the high-priced work tho it takes but little for maintenance. This is because there is a big annual interest charge against the costly road, while the cheap one represents but a small investment. Are we getting the most possible on our investment?

This is a common situation. A lot of money, raised by taxation or bond issues, is used to build a road which serves the comfort and convenience of the community. Having thus been made much better than the adjacent older highways, it generally attracts travel from them, and the traffic over the new road becomes greater than before improvement. Then, irrational and unwise as it undoubtedly is, this splendid new roadway, with its heavier traffic, subject to deterioration by weather and use, is absolutely left to shift for itself, while the attention of the road authorities is turned away and concentrated on some other piece of new construction.

The result, of course, is what might be expected. Soon little defects appear, and once started, these rapidly grow serious. If the neglect continues, it will be but a short time until the road is substantially as bad as before the improvement, and a very large part of the expenditure has been practically wasted. Nor does a little ill-considered patching once or twice a year amount to anything. Continuous inspection and repairs is the only keynote to success.

It is indeed a marvelous commentary upon the intelligence of the American tax-payer that for more than a century he has put untold millions upon the roads in precisely this unproductive fashion! Can't the national mind be awakened from its lethargy to the question, "Why is the maintenance of our roads neglected and inferior to that of other countries?"

The answer is simple: In this country, road construction has been allowed to interfere with and prevent proper road *maintenance*. In a new country, the construction of roads of

some kind is first necessary, and of absorbing importance. In a country as vast as this, it has been impossible to construct all the roads demanded as fast as they were needed.

141. Worth Having — Worth Saving.— There has been a tendency to utilize all available funds for construction work, leaving the roads already built to shift for themselves. This is a wasteful and expensive policy, and retards good road construction. Provision should be made for the upkeep of a road just as soon as it is completed, and the funds provided for maintenance should not be allowed to be used for any other purpose. Maintenance is perhaps, the hardest problem to be solved at the present time in connection with public road work, but its correct solution vitally affects the success or failure of road work generally.

142. Centralization Needed.— Viewing public roads as a whole the defects of small administrative units are conspicuous. The number of men who have more or less authority and personal direction over road matters in this country is extraordinary. Continuity of policy is impossible. The term of these men is but a year or two, and rotation in office is the usual rule. Thus, just where the stimulus of effective organization is most needed it is absent. The only successful attempts at systematic repair and maintenance on record are those which have been managed with skilled and strong *central* control. The systematic employment and retention of trained highway engineers has been found essential. Almost without exception, those States which have undertaken State Aid in any form for road-building have, in their annual reports, reiterated the necessity of removing the responsibility for repair and maintenance of such roads from local authorities. In a number of States this change has been made, and the results have been an immediate improvement.

143. Competency the Keyword.— The rapid deterioration of our roads has been especially noticed by the automobilist, and he specially questions its cause and remedy. Where formerly in many sections, road-building was considered work that most anybody could do, and any surveyor could locate a road *satisfactorily,* it is now realized that road-building is a profes-

sion, the supervision of which requires the services of a competent, well-trained road engineer, who is capable of seeing:

1. That the road is located in the right place.
2. That it is graded properly.
3. That it is thoroly drained.
4. That it is surfaced with material adapted to its traffic.
5. That culverts and bridges are of the right size, in the right places, and built of suitable material.
6. That an economical method of maintaining the road is put into force.

The solving of these problems requires skilled and capable men, especially when a minimum amount of money must accomplish a maximum amount of work.

144. Training Needful.— A fundamental difficulty with the organization to handle the repair and maintenance of road systems lies in failing to recognize that road work is a trade, and requires training. This is necessarily obtained at the expense of the community. Actual practical experimentation must supplement even the best theoretical knowledge. As a rule, officials are not in office long enough to mature their experience, and hence there is a constant waste of road funds.

Repair and maintenance operations upon all public roads necessarily extends over a period of years. In order to secure their effective execution, a comprehensive plan for several years is necessary. The work for each season must be carefully laid out as far in advance as possible. Where maintenance work has been seriously undertaken under such a system it has responded with gratifying results.

145. Continuity in Service.— Does a manufacturing plant get best results by periodically employing all new men? The best results follow in an administrative district where the mileage of roads requires the continuous employment of a man who is either a highway engineer or a competent road-builder, whose interest is primarily in road work, and who has actual charge of road matters in his district. Where such a man is employed from year to year he can select competent men for road work, and is able to plan with confidence systematic improvements

which must wait for successive annual appropriations. The community thus invariably gains the benefits of the experience it has paid for.

146. Maintenance Plans.— Individuals to carry on maintenance work should be selected simply and solely for economy and efficiency. But though such selections are made with the intention to select the best possible men for the place, the lack of definite agreement with some higher authority as to what, where, and how the work should be done, and the character of results required, it happens that the work is performed when it best suits the individual who has it to do. That is, he will work on the road when he has nothing more important on hand, and as he is the judge of the relative importance of the work before him, he very naturally puts his personal interests above those of the community. Under this neglect of the road inferiority of results is bound to occur.

Another system of so-called "maintenance" appoints an individual for a considerable section of the highways in a territory covered by the central authorities, and places to his credit a limited, but often fairly large sum (a portion of the general road funds) to carry on repairs to the roads in his section. Sometimes this man receives no salary, or only a nominal one, for his services. In this case, the objections just stated apply with equal force.

Under another plan the district or sectional authority is paid a sufficient salary for the time and services required. Even with proper pay the conduct of the work is in most cases uneconomical, inefficient, and unsatisfactory. The usual procedure has been to get together a gang of men and teams and start out over the roads either before the time for farm work to begin in the spring or after the harvest in the fall. Taking the roads consecutively, it is attempted to do the year's work all at one time, and that a very short time. The repairs are intermittent and irregular, instead of constant, regular, and careful.

147. Essentials of Scheme.— Of the methods in vogue in various sections of the United States, some work satisfactorily, and others do not. The main requirement is that the road

shall be repaired at the time it needs it, and without any unnecessary delay, recognizing that the maintenance can be done cheaper and to better advantage, if the road is repaired just as soon as it begins to deteriorate. It is just as necessary to inspect the public road at definite intervals as it is to inspect railroads; and the best results can be obtained where a definite length of highway is under charge of a supervisor who has authority to hire extra hands when necessary to repair any exceptional damage that has been done, either by heavy rains, washouts, or heavy traffic. These supervisors should be under the control of the county or district engineers or superintendents, and be provided with all necessary tools and supplies with which to repair the road under their charge. The supervisor can also notify the superintendent of needed repairs which the supervisor is unable to make himself.

148. Continuous Maintenance the Keynote.— No man can "Serve two masters" properly. A man cannot run his farm and at the same time properly attend to maintaining several miles of highway. The interests and demands of the two kinds of business conflict. When it is good weather to work on the roads, it is also good weather to farm. When the weather is bad for farming, it is against the interests of the road to "put in time" for farm labor and horses on them. There is one exception to this, but it does not materially affect the rule. That exception is in using the road drag. Being convenient to his road with his team, the time for the drag's best use is when weather conditions permit a team to be well spared from the farm work. Thus the farmer can be of valuable assistance in the maintenance department of a country road system, but if he wants good roads generally, and efficient expenditures made, specialists must be employed. He must usually be content to occupy this small but important place in a county road department. Doing this, he will be well repaid in the results.

149. Systematic Effort.— The Highway Commission of Ohio, 1913 Report, has the following remarks on system:

"In each township or group of townships sufficient to warrant it, there should be a road superintendent devoting his

entire time to the work, at a salary adequate to secure the services of a competent man. Upon him should rest the entire responsibility for the proper maintenance and repair of the roads within his district.

"The method of working out the road tax whereby each person works under unskilled management accomplishes but little good. The work should be under the supervision and direction of an experienced man, with the necessary permanent laborers under him, thus preventing an entire change of force every day or two."

" If more than dragging the road is contemplated, a definite plan of permanent improvement should be adopted and, if followed thru a period of years, a system of good roads will result. Cut down the steepest grades, and grade up and improve the cross-sections of the worst portions of the roads first, giving due consideration to the amount of travel on the road."

150. Maintenance with Scraping Graders.— Where there is a considerable mileage of earth roads, the scraping grader is often found to be more economical than the road drag. Work should be started in the late spring after the worst rains are over, and after the ground has dried out fairly well. The ground has then settled after the expansion due to freezing and thawing out, and is in the best shape to be worked. Then the grader can be used to the best advantage, and the machine should be run over the road, starting at the ditches and working towards the crown, as in new road construction. Set the blade so it will just plane off all ridges, and fill the ruts worn in the road during the winter and early spring. Use the entire width of the blade in maintenance, set square across the road. This will carry considerable earth alone in front of the blade, and fill the ruts better than if the blade were set at an angle. All depressions will also be filled up, and very little earth will be worked toward the center of the road. This is correct as only enuf earth is wanted on the crown to replace what has been washed down by the rain.

Don't wait too long before starting this work, or until the road is so dry that it is impossible to compact the material

moved in leveling-off. This does not mean that the road should be soggy and soaked. A good rule to follow is that if the surrounding fields are a little too wet to properly work, the road can be worked to the best advantage.

A scraping grader can also be used during the summer instead of the drag if the road gets rutted and in bad condition. Such work should, however, always be done soon after a rain.

151. Cost.— The cost of repairing roads in the spring with the scraping grader is small. The money that is wasted in five years in almost any community would usually pay for the necessary grader. Its repairs and depreciation are comparatively small. Four or six horses will be required, according to the conditions of the roads. With two teams and drivers at four dollars per day each, and a man operating the grader at two dollars per day, the maximum cost would therefore be but ten dollars per day for four horses and three men. This outfit should average three miles a day, allowing for bad weather, so that the cost per mile would be only about $3.33, and if repairs are included, the cost would not be over $3.75 per mile on the average.

152. Road Patrols.— Minnesota has a road patrol system. One man is appointed for a section of about six miles. He is provided with a wheelbarrow and kit of tools, rake, shovel, pick, scythe, axe, or whatever may be necessary for this work. Such a man is generally selected, not because of his superior qualifications as a road-builder, but because he will obey orders and work without being watched. These road patrols wear a brass hat plate, with "State Road Patrol" thereon, which permits them to be identified by travelers and seems to encourage them to take an interest in their work. The pay is $55 per month, from April 1st to November 15th, depending on the weather conditions. The plan is to have the patrol on the ground while the water is going off in the spring, and to keep him until after freezing-up in the fall. Some modification of this plan might become necessary under different local conditions, but the general plan widely applied is one that would result in vastly improved road conditions and would be more satisfactory to the road user and tax-payer.

DUTIES.— He first becomes familiar with his section by walking over it to learn its general condition, especially noting points that require immediate attention. Such patrolling is thereafter done over the entire length of the section at least once in each two weeks. Serious defects discovered are attended to at once, and afterward the worst places receive attention in their proper order. The methods of maintenance on sand, clay, or gravel roads are practically the same in detail as for earth roads, except that piles of material are arranged on the latter at convenient points for general repairs.

It is probable that the continuous employment of road patrols will be too expensive for the greater part of our road mileage for some time to come. It is equally true, however, that on many miles of improved road the presence of a road patrol at a cost of from $60 to $75 per month will be economy. It has been repeatedly observed that the work of such roadmen in preventing water breaks and wash from rainstorms and thaws at the right time has in itself justified their salaries.

153. Maintenance by Dragging:— *Theory of Operation.*—No road will long endure without maintenance. The price of good roads is eternal vigilance in maintenance. This is more true of earth roads than of any other. Rains and melting snow soften the surface more or less, and passing traffic forms ruts and depressions. These, if allowed to remain, retain more water at the next rain and more mud, deeper ruts, and larger depressions are formed. It is self-evident, therefore, that the main effort in maintaining heavy soil or any other earth roads must be to keep the drainage good. For this purpose there is nothing which equals the split-log drag or other similar device.

The principle of the drag is simple: Clays and most heavy soils will puddle and set very hard if worked when wet. The drag is essentially a puddling machine. After each rain and while the earth is still plastic, but not sticky enuf to adhere to the drag, one or two trips up and down the road is made with it. Only a small amount of earth is moved, just enuf to fill the ruts and depressions and smooth over the surface with a thin layer of plastic clay, which packs under passing traffic and leaves the road smooth and hard if of the right material. The next rain, finding no ruts and depressions in which to collect, runs off, affecting the surface but little.

Twenty or thirty dollars per mile per year seems to be about the average cost of dragging in the Southern States. The essential thing is doing the work when it is needed. This is the point which seems hardest to impress on the average man. The little attention the earth road needs must be given promptly and at the proper time if we wish to secure any results. So accustomed are we to the old habit of doing road work at our convenience in the spring or fall of the year that we can hardly force ourselves to realize that anything else should be even suggested. Yet it is certain that we will never have anything like the earth roads we can have until we adopt a system of continuous maintenance. The amount of work required at the time is usually small, but promptness is imperative, else the amount will be large, and the roads bad for long periods of time.

154. Dragging.— "Drag, drag, and then drag a little more if you want to insure good roads." There is probably no time during the year when a drag will not improve a dirt road. The object is to secure a smooth surface and to mend the little holes in the roof of the road. As every passing vehicle has an effect sometimes good, sometimes bad, it is plain that every reasonable precaution should be taken to keep the road surface good all the time. This cannot be done, it if is permitted to become filled with chuck-holes, ruts, or depressions retaining water.

In the spring don't wait until the road settles to get out with the drag. Smooth it off and puddle the surface as soon as the frost begins to go out. If the road becomes cut up later, drag it again and again as it needs it. It will not only keep it in good condition during the spring but will pack the surface and make it easier to maintain during the summer and fall months.

155. The Best Time to Drag.— Roads should be dragged when they can be smoothed with the least possible labor. That is when the ground is in condition which in a field would be considered about right or a little too wet for plowing. It should be moist enough to break and distribute but not enough to shine when the drag passes over the loose portions.

Dragging is a part of the drainage work on the road. Its effect toward road preservation lies in the fact that a dragged road is smooth and has a reasonably uniform slope. Hence a heavy rain passes rapidly to the side ditches and the road has an opportunity to dry out quickly. Breaking up the compact traveled path by the introduction of moisture is thus prevented.

In theory the drag does not undertake to trowel a road to make the surface hard. It is often beneficial to drag the road immediately after a rain when the water is standing all over it and it is in a sloppy condition, permitting the water to escape if the road has not been kept smooth. Also before a cold wave such action will often result in providing a smooth roadway while frozen. Where the road has been given any care and the water runs off, the dragging should be done when it breaks down the rough points and fills depressions with the least time and effort, permitting travel to complete packing the soil.

156. Dragging Not a Cure-all.— It is always possible to have "too much of a good thing." While recognizing the value of the dragging, notice the comment of an Oregon road-builder, remembering that Oregon has greater rainfall than most inland States.

"Two features have lately been largely exploited. Crowning and drainage, really one and the same thing, and the use of the split-log drag have been extolled as the last word in earth-road improvement. If they were insufficient, then the only recourse was hard surfacing. Both of these features are valuable in road maintenance, but neither touches the essential factor in constructing a servicable earth-road bed."

"Extensive observation of country roads shows places where dust is never troublesome even in the driest weather, and where the mud never gets deep enough to obstruct travel. Investigation invariably shows that the roadbed has a foundation of stone in some of its forms. It may be ledge rock, shell rock, broken stone, gravel or coarse sand, but it is never fine earth that is free from stone."

157. Foundation Needed.—

"Under ideal conditions a roadbed of loam or clay cannot be improved upon. But ideal conditions cannot be secured at all times. Given sufficient rainfall and enuf traffic, and any loam or clay surface will become a mass of mud regardless of crown, drainage, or previous use of the log drag. If both rainfall and heavy traffic are continued long enuf the only limit to the depth of the mud will be the ability of the teams to haul the wheels through, unless a stone foundation is first reached."

"There are miles of road in western Oregon that a few years ago were literally

bottomless bogs for several months in every year. They are now fairly good at all seasons. The change was wrought by simply dumping enuf broken stone in the mud along the center-line of travel to form a bed that would carry the traffic. This stone was roughly spread or left to spread itself. The compacting was done by feet and wheels. All this is undoubtedly very crude and unscientific. Perhaps we should not advise or encourage such primitive methods; but the fact remains that these methods do secure desirable results."

"The road drag has greatly reduced the number of days during which the average dirt road is not fit to travel. But it can never make, out of a loamy soil, a highway which will be able to withstand a long continued rainy spell combined with any considerable amount of traffic. It will not build roads."

"It is a great implement. It has done wonders for our dirt roads. It will continue to do wonders if properly used but it has the limitations and these must be recognized by its friends if they do not wish to become ridiculous."

158. Dragging Organization.— In maintaining dirt roads they should be divided into sections, with a foreman or overseer in charge of each, who should go over all of it after every rain or at least every two weeks, without rain. Wherever he finds repairs needed, he should have it done. After each heavy rain he should run a road drag over the road in order to bring it into shape and to fill up any ruts or holes that may have started. Roads will not maintain themselves, and repairing a road simply once a year will not keep it in good condition.

159. Drag System in Minnesota.—

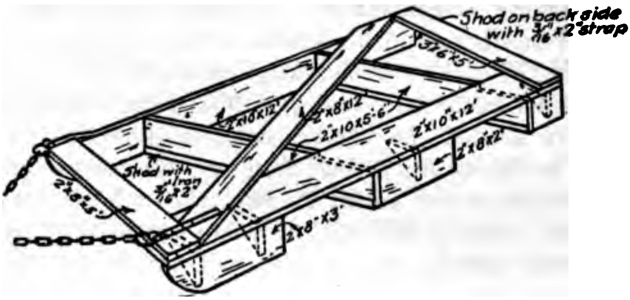
"A Superintendent of Dragging is appointed by the county board. He contracts with residents along the State Roads to drag them after each rain or whenever ordered by him. He also has a road grader and employs an engine or teams to operate it, when occasion requires. He devoted all his time to directing general repair work and maintenance and sees that the contracts are properly executed. This system is especially applicable to the prairie and gumbo sections of the State."

"Compensation for the different classes of work vary, but on a basis of $2.00 for men and $4.00 for teams, a reasonable compensation would be about as follows: $50.00 per month for Road Patrol; $85.00 per month for Section Foreman or Drag Superintendent, including expenses and the use of team; and 80 cts. per mile for double dragging, or 40 cts. per mile for a round trip. Payment for this service must first be made by the county, upon certificate of approval by the engineer, and State Aid thereon will be granted upon report of the County Auditor, which report includes engineer's certificate."

160. Winter Dragging.— Minnesota has had experience, and especially recommends the dragging of roads in winter, even after they have frozen up, especially if rough when frozen. The sharp points become softened and dried out a little by sun

and wind, when they may be planed off, not only making the roads much smoother and better for the remainder of the winter, but helping them immensely when they break up in the spring. Where this has been tried the value of the procedure is most fully appreciated.

161. Road-Planer.— For the above and similar road work Minnesota has evolved a device known as a road-"planer." It is fashioned something like a sled, but carries two iron-shod edges on vertical cross-bars set askew of the runners. For details of its construction,— home-made,— see accompanying cut.



Minnesota Road Planer.

The split-log drag, so-called, is a justly celebrated tool. Continued use of it alone as a road-making tool has often resulted in a distinctly wavy surface, very unpleasant to ride over, and further use of the drag seems only to emphasize the trouble.

It is this difficulty that the planer especially solves, since its runners prevent it falling into the low places, hence it of necessity planes off the high spots, and fills up the hollows.

It has been found that newly constructed gravel roads are especially benefited by the planer, since the use of it while the surface is being compacted under traffic prevents ruts and waves from forming. The best results will be obtained when the materials are fairly soft and plastic, as after a rain. Macadam, or crushed-stone roads that are built without rolling, relying upon traffic to solidify their surface, can be readily

kept free of ruts and waves, and up to the proper cross-section by the planer. When fully compacted, however, the planer should be used with caution, as it is likely to loosen any projecting stones, and will cause the surface to ravel.

162. How to Drag.— Like many another simple operation, the split-log drag or planer is only successful when handled right. First, the pace of the horses should be a walk. Second, the hitching-link should be in such a position that the runners stand at an angle with the road when the driver stands in the line of draft, especially if considerable material is to be moved up onto the road. The runners will stand more nearly in line with the center-line of the road, and the blades, either of drag or planer, more nearly square across the road, according as a greater or less amount of material is to be moved. In this way just enuf material is collected in front of the cutting edge to carry along and fill the little depressions and ruts. It is not enuf to form a pronounced ridge in the center producing dust and mud, and prohibiting traffic upon the crown of the road,— a most sad and unintelligent condition, however it originates.

The driver must not sit on the drag, but stand, shifting his weight to vary the depth and position of the cutting as local conditions demand. By moving at the right moments from one side of his drag to the other, he can collect or deposit a load of material at will.

163. Summary of Rules for Dragging:— (Minnesota)

Get a system.
Drag after every rain.
Use a light drag.
Drag when the road is wet, not sticky.
Ride the drag.
Shift weight as needed.

DON'TS.

Don't delay.
Don't drag when too dry.
Don't try to take too much in one trip.
Don't neglect your winter dragging.

CHAPTER VIII

WATERWAYS

Water is the greatest destructive element affecting earth roads. The road-builder constantly struggles against it. The drainage structures form a vital part of any road, and commonly absorb a very large share of all road moneys. This chapter explains the inter-relation of the numerous factors affecting the economical expenditure of such money.
Thus, culvert materials, their size, strength, location, and methods of construction, are treated at length. The forces tending to destroy them are indicated, with methods of guarding them from destruction.
Costs and quantities of materials are given, especially of concrete, to the end that prices paid shall fit the work's worth. Considerable detailed instruction in handling concrete, and in selecting its materials, mixing, inspection, form-building, etc., is given. There is a practical discussion of foundation problems affecting the road builder, a description of the various types of pipe culverts, with practical data on small stone arches, and moderate-span concrete slab bridges.

164. Classification of Types. — Culverts are small waterways crossing the roadway, called "wet" or "dry" as they provide for living streams, or for occasional surface water due to heavy rains. The distinction between a culvert and a bridge is rather vague, but generally all waterways not requiring special design, of moderate size, and which can be built on standard plans are classed as culverts.

A convenient tho arbitrary distinction for country roads, used by some, is to class all waterways requiring no guard-rail for the protection of travelers as culverts, and structures requiring such protection as bridges.

Another classification especially chosen to distinguish between work to be done by the county, and that by townships, called everything over a 20-ft. span a "bridge" and structures of lesser size a "culvert." Unfortunately, probably many "bridges" were built under this plan where culverts were really called for, and the long-suffering public paid the bills, as they always must.

165. Materials. — Formerly wood was a common material for both culverts and bridges on country roads. Many other materials have now come into common use. Pipes of vitrified clay, cast iron, and corrugated metal are used for small drains;

brick, stone, and concrete are used for variously shaped small openings, and for larger culverts and bridges. The use of concrete is to be commended. It is a material reasonably cheap in most localities and permanent when properly placed in structures properly designed; but too much stress can not be laid upon the care required in using it. Each of these materials has its merits for use in different sections, and for different locations on the roads. A blind faith in any one of them shows a lack of good judgment.

166. Selecting the Proper Type. — Determining the kind of waterway to use is a matter of experience and judgment, based in general upon the following factors:

1. Cost. Depending on (*a*) Availability of material and labor; (*b*) Character of foundations.
2. Type of the road for which it is built, i.e., importance and cost of the whole project.
3. Size of opening necessary.
4. Headroom available, i.e., distance from water surface to road surface.
5. Convenience of construction and character of the soil.

Standard plans, and their quantities, which may assist in making a proper choice of culvert type are shown herewith, representing what Massachusetts and North Carolina have done in this direction. Since these cuts show the complete details, in each case, reliance may be placed on them for guidance in ordering materials and actual construction.

167. — 1. The factors affecting the amount of money a county or road district is warranted in expending on culverts and small bridges are briefly summarized thus:

(*a*) Safety and convenience require them to be in good condition at all times, since a failure stops travel and may injure travelers.

(*b*) A permanent culvert, while more expensive to build, is less expensive than one which must periodically be wholly rebuilt.

(*c*) Repairs are largely eliminated in permanent culverts, and small repairs to small culverts are very expensive in proportion to the cost of materials used.

BOX CULVERT DIMENSIONS

SIZE	"a"	"b"	"c"	"d₀"	"d₁"	"e"	"f"	"g"	"h"	"i"	"j"	"k"	"l"	"m"	"n"	"o"	"p"
2x2	2'-0"	2'-0"	6"	7"	12"	24"	24"	9"	3'-3"	6"	12"	13"	5'-0"	No Counter-forts	2'-6"	18"	24"
3x3	3'-0"	3'-0"	6"	8"	12"	24"	24"	9"	4'-9"	6"	12"	13"	6'-0"		2'-9"	18"	24"
4x4	4'-0"	4'-0"	6"	9"	12"	24"	24"	9"	6'-3"	6"	12"	13"	7'-0"	4'-0"	3'-0"	18"	24"
5x5	5'-0"	5'-0"	7"	10"	12"	25"	24"	9"	7'-9"	6"	12"	13"	8'-0"	5'-0"	3'-3"	18"	24"
6x6	6'-0"	6'-0"	8"	11"	12"	26"	24"	9"	9'-3"	6"	12"	13"	9'-0"	6'-0"	3'-6"	18"	24"

SCHEDULE OF REINFORCING RODS

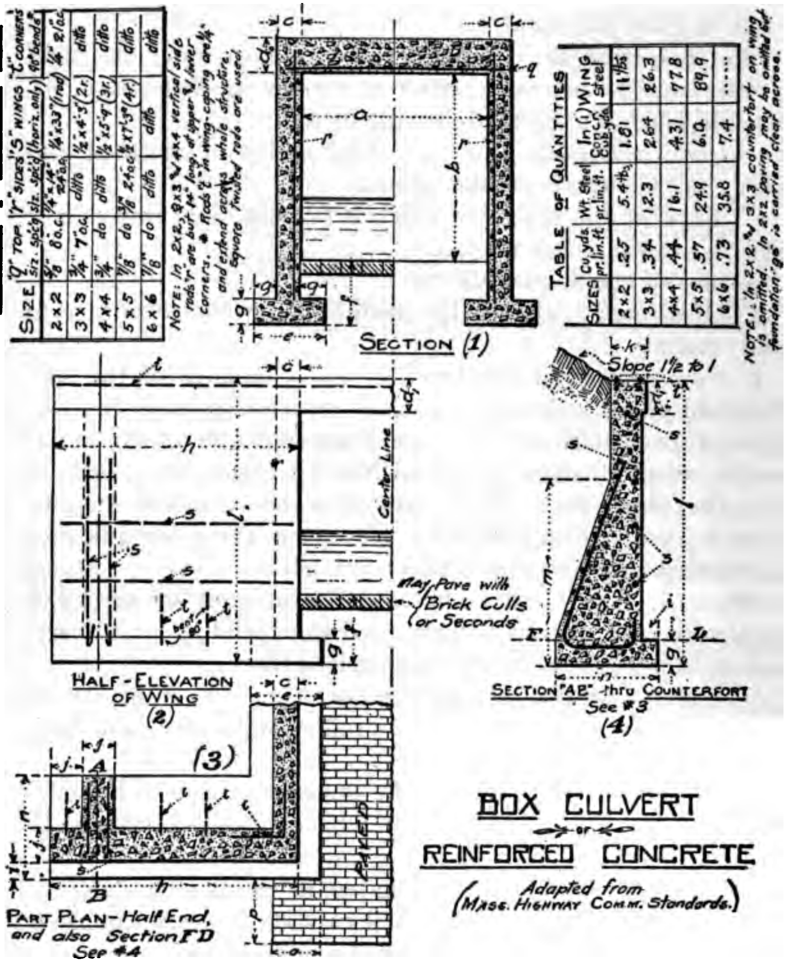
SIZE	"q" TOP siz. spc'g	"r" SIDES siz. spc'g	"S" WINGS (horiz. only)	"t" CORNERS 90° bends*
2x2	5/8" 8" o.c.	1/4"x1/4" 24" o.c.	1/4"x33" (1 rod)	1/4" 21" o.c.
3x3	3/4" 7" o.c.	ditto	1/2"x4'-3" (2 r.)	ditto
4x4	3/4" do	ditto	1/2"x5'-9" (3 r.)	ditto
5x5	7/8" do	3/8" 24" o.c.	1/2"x7'-3" (4 r.)	ditto
6x6	7/8" do	ditto	ditto	ditto

NOTE: In 2x2, 3x3 & 4x4 vertical side rods "r" are but 14" long, at upper & lower corners. * Rods "t" in wing-coping are 1/4" and extend across whole structure. Square twisted rods are used.

TABLE OF QUANTITIES

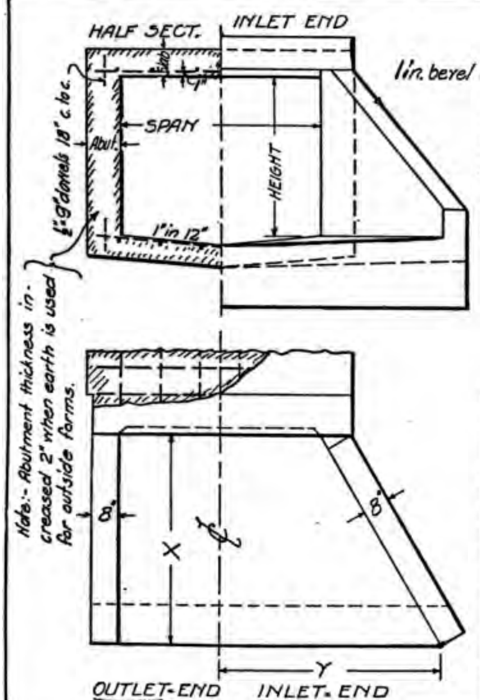
SIZES	Cu. yds. pr. lin. ft.	Wt. Steel pr. lin. ft.	In (1) WING Concr. Cub. yds.	In (1) WING Steel
2x2	.25	5.4 lbs.	1.81	11 lbs.
3x3	.34	12.3	2.64	26.3
4x4	.44	16.1	4.31	77.8
5x5	.57	24.9	6.0	89.9
6x6	.73	35.8	7.4	......

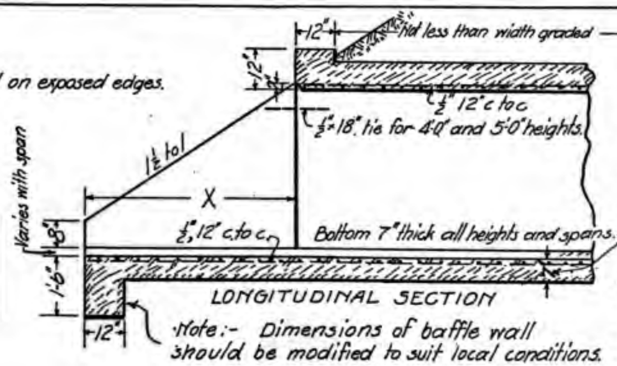
NOTE: In 2x2 & 3x3 counterfort on wing is omitted. In 2x2 paving may be omitted & foundation "g" is carried clear across.



BOX CULVERT
-or-
REINFORCED CONCRETE

(Adapted from Mass. Highway Comm. Standards.)

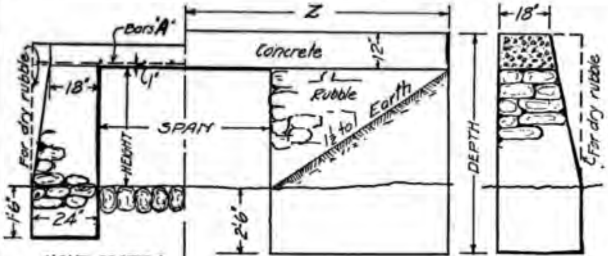




HEIGHT	SPAN	THICKNESS ABUTMENT	THICKNESS SLAB	LENGTH WING (X)	½ WIDTH WING END (Y)	BOX SECTION					INLET END		OUTLET END	
						STEEL								
						TOP	BOTM.	DOWELS	WEIGHT LIN. FT.	CONCRETE LIN. FT.	CONCRETE	STEEL	CONCRETE	STEEL
Ft	Ft	Ins	Ins	Ft. Ins.	Ft. Ins.	Size	Size	Size	Lbs	Cu. yds.	Cu. yds.	Lbs.	Cu. yds.	Lbs.
1½ ×	3	8"	7"	1'-4"	2'-3"	½@5"	½@6"	½@9"	24.6	0.261	0.60	25	0.61	22
2 ×	2	8"	6"	2'-2"	2'-3"	½@6"	½@6"	•	19.1	0.234	0.69	28	0.62	26
2 ×	3	8"	7"	2'-1"	2'-8"	½@5"	½@6"	•	24.6	0.285	0.80	35	0.75	30
2 ×	4	8"	8"	2'-0"	3'-2"	½@4"	½@5"	•	36.5	0.345	0.92	41	0.87	35
3 ×	3	9"	7"	3'-7"	3'-7"	½@5"	½@6"	•	24.6	0.360	1.37	50	1.19	40
3 ×	4	9"	8"	3'-6"	4'-1"	½@4"	½@5"	•	36.5	0.421	1.52	75	1.26	60
3 ×	5	9"	9"	3'-5"	4'-6"	¾@7"	½@5"	•	56.2	0.478	1.64	100	1.41	85
4 ×	4	10"	8"	5'-0"	4'-11"	½@4"	½@5"	•	36.5	0.513	2.27	120	1.73	95
4 ×	5	10"	9"	4'-11"	5'-4"	¾@7"	½@5"	•	56.2	0.580	2.50	130	1.91	109
5 ×	5	10"	9"	6'-5"	6'-3"	¾@7"	½@5"	•	56.2	0.644	3.33	151	2.45	132

REINF. CONCRETE BOX CULVERTS

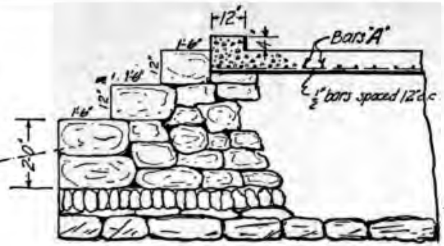
NORTH CAROLINA STADARDS



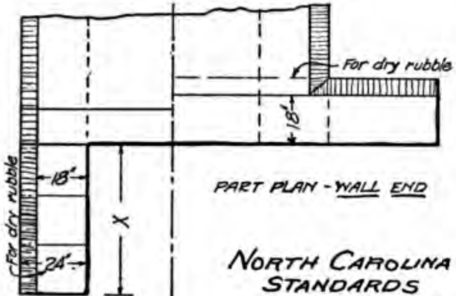
HALF SECTION

HALF WALL END

SECTION—WALL END



LONGITUDINAL SECTION
— OUTLET END —



PART PLAN
— OUTLET END —

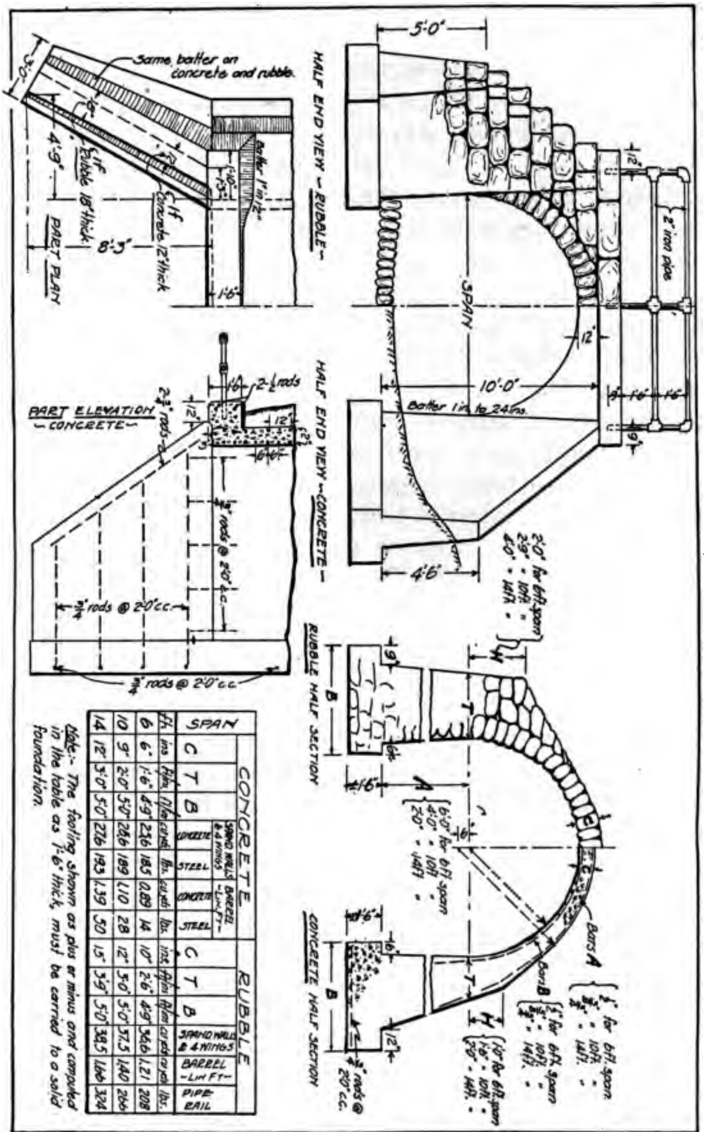
PART PLAN - WALL END

NORTH CAROLINA
STANDARDS

HEIGHT	SPAN	THICKNESS COVER STONE	*CONCRETE SLAB (lin. ft.) THICKNESS	CU. YDS.	STEEL BARS "A"	STEEL WEIGHT (TO BAG)	ABUTMENTS CU. YDS.	WALL END Z	B	CONCRETE	STEEL	STONE	OUTLET END X	CONCRETE	STEEL	STONE
ft.	ft.	ins.	ins.	lin. ft.	ins.	lin. ft.	lin. ft.	ft. ins.	ft. ins.	cu. yds.	lbs.	cu. yds.	ft. ins.	cu. yd.	lbs.	cu. yd.
2 × 2		10	6	0.09	½@6"	11.8	0.26	4'0"	2'0"	1.89	0.44	11.8	3'0"	1.33	0.28	11.8
2 × 3		12	7	0.13	½@5	15.6	0.46	4'6"	2'0"	1.89	0.50	15.6	3'0"	1.33	0.33	15.6
3 × 3		12	7	0.13	½@5	15.6	0.58	6'0"	2'6"	3.42	0.67	15.6	3'0"	1.50	0.33	15.6
3 × 4		14	8	0.17	½@5	19.8	0.58	6'6"	2'6"	3.42	0.72	19.8	3'0"	1.50	0.39	19.8
3 × 5			9	0.22	¾@7"	23.4	0.58	7'0"	2'6"	3.42	0.78	23.4	3'0"	1.50	0.44	23.4
4 × 4			8	0.19	½@5"	19.8	0.72	8'0"	2'9"	5.33	0.89	19.8	4'6"	1.76	0.39	19.8
4 × 5			9	0.22	¾@7"	23.4	0.72	8'6"	2'9"	5.33	0.95	23.4	4'6"	1.76	0.44	23.4
5 × 5			9	0.22	¾@7"	23.4	0.84	10'0"	3'0"	7.64	1.11	23.4	6'0"	3.67	0.44	23.4

Note:- Quantities based on rubble laid in cement mortar
* Slab must extend across abutment top for dry rubble.

RUBBLE AND SLAB CULVERTS



SPAN	CONCRETE C	T	B	SPAND WALLS & 4 WINGS CONCRETE	STEEL	BARREL –LIN FT– CONCRETE	STEEL	RUBBLE C	T	B	SPAND WALLS & 4 WINGS	BARREL –LIN FT–	PIPE RAIL
ft.	ins	ft/ins	ft/ins	cu.yds	lbs.	cu.yds	lbs.	ins	ft/ins	ft/ins	cu.yds	cu.yds	lbs.
6	6"	1'-6"	4'-9"	23.6	185	0.89	14	10"	2'-6"	4'-9"	36.6	1.21	208
10	9"	2'-0"	5'-0"	28.6	189	1.10	28	12"	3'-0"	5'-0"	37.5	1.40	266
14	12"	3'-0"	5'-0"	27.6	193	1.39	50	15"	3'-9"	5'-0"	38.5	1.66	324

Note:- The footing shown as plus or minus and computed in the table as 1'-6" thick, must be carried to a solid foundation.

ARCH CULVERTS, NORTH CAROLINA STAND.

There may be cases justifying the use of non-durable material, but as a rule the less durable the material the more expensive the culvert is in the long run. The relative cost of different types of culverts varies greatly in different sections, but the approximate probable ratio of variation in cost is shown in Section 172.

2. The more permanent the nature of the road surface, the more lasting should its culverts and bridges be. Thus, a small timber structure would not be used on a road if $4000 to $10,000 per mile were being expended on the surfacing. On the other hand, for a comparatively unimproved road in a timbered country, a wooden structure may be economical and justifiable.

168. — 3. The size of opening, or waterway required, influences the type of material which may be used. Vitrified pipe is not ordinarily used for diameters greater than 24 inches. Cast iron and corrugated pipe are used for diameters up to five feet. Other materials may be used for all sizes.

4. The headroom may be such as to prevent the use of arches, or may require the flat-slab type to be used. Vitrified pipe should not be used unless there is sufficient headroom to provide a suitable protecting cover of earth above the pipe, guarding it from the shocks and blows of traffic.

169. — 5. It frequently happens that materials are at hand which can not be otherwise used, or foremen can do better work with certain materials, or the progress of other portions of the work are involved. Such conditions as these may make it advisable to use a special type of culvert, or easily-cut soil may require paved bottoms or specially designed outlets.

The selection of the proper material and type of culvert is a problem worthy of careful consideration by the road official. The correct solution results in a considerable saving of money.

170. — Proper culverts and bridges bear an intimate relation to highway improvements, absorbing frequently as much as 40 per cent of all road expenditures. Yet the economy of building them of durable and permanent materials, used in intelligent, economic designs has not been generally recognized. Many communities continue old-fashioned, inadequate

and expensive methods of construction and repair of their bridges and culverts, yet modern traffic conditions demand that their construction shall keep pace with the industrial development of the country.

The administration of road improvements in the United States is placed in the hands of local officials. The bridge improvements of many of these communities are mainly the construction or repair of culverts and small span bridges which seemingly do not justify the expense of securing an engineer's advice. This text is intended to assist local officials in securing a proper, intelligent and economic design for culverts and small bridges.

171. — Structures larger than 20 feet in span should never be undertaken without consulting an engineer. Many states maintain an engineer to give free engineering advice to local officials requesting it, and the State Highway Commission should always be consulted by communities contemplating extensive bridge improvements.

The substantial construction of bridges is an important feature in the welfare of any community. Travel is demoralized when they are unsafe. When planning a highway bridge, traffic conditions should be considered carefully and the bridge constructed not only to meet the present traffic requirements, but also those of the future. The bridge of today must be strong enough to allow the passage of heavy traction engines, road rollers and motor trucks. It should advertise the progressive ideas and business activity of the community and therefore should be built of a permanent structural material. It will not then require costly or frequent repairs.

172. — Concrete is peculiarly fitted for this construction. Concrete bridges are nearly permanent if properly constructed, and do not wash out or require painting. They are made of materials most of which can usually be purchased in the vicinity, and permit the greater part of their cost to be spent at home. For simplicity of construction and durability, it leads all other types. It is claimed that the following table fairly compares the ultimate cost of culvert construction with the different materials:

Kind	Shape	Size	Cost	Cost for 100 Years
Wooden Box	Rectangle	15″ Square	$16.80	$252.00
Concrete Box	Rectangle	15″ Square	40.00	40.00
Cast Iron	Semi-Circle	16″ Diam.	57.00	97.00
Cast Iron	Sector	18″ Diam.	65.00	112.00
Cast Iron	Circle	18″ Diam.	92.40	166.80
Vitrified Tile	Circle	18″ Diam.	42.00	42.00
Corrugated Steel	Circle	18″ Diam.	50.40	196.00
Circular Concrete	Circle	18″ Diam.	35.00	35.00

173. Proper Location. — After examining the foundation at a proposed bridge site, it is often found necessary to change the location to secure a more suitable and economical foundation. In the layout of a new bridge, careful attention should be given to the probable later improvement of the roads. The general alinement of the road should be planned so as to be practically straight. Short, sharp curves at a bridge approach are dangerous, but we often see a bridge built to fit the stream only, utterly disregarding the sharp turns necessary to use it. For culverts the waterway should be placed where the greatest flow of water occurs during heavy rains. Otherwise the culvert's capacity is decreased and the probability of washouts increased. It is remarkable how often this simple rule is neglected.

The best outlet for the water may largely control the location. Ordinarily water that has passed thru the culvert and cannot get away prevents other water from flowing thru and the road is flooded from both sides. If possible, a broad, straight outlet and inlet should be provided. In case this is a ditch it should have flat side slopes, and, if bends are necessary, they should be at some distance from the culvert.

Many culverts are destroyed by *undermining* at the lower end. In examining the site the character of the soil should be noted and, where necessary, provision made to prevent erosion. The angle at which a culvert crosses the road is *important*. While they should be placed in line with the principal

Seems to have been something radically wrong with these concrete jobs, also. Upper one lasted two years. Lower one collapsed afterward.

flow of water, they are generally placed at right angles to the road, tho this seldom matches the stream exactly. If they do not line up with the stream substantially, clogging, resulting in a washout, may easily occur. But placing them askew to fit the stream requires greater length, and also increases the cost and difficulties of building the head- and wing-walls. On a steep hillside where a culvert limited in size must be used, or where the course of the stream can not be readily changed, as where rock is encountered, it may be advisable to place it on a skew. Only in rare cases, however, will the advantage gained offset the added cost of the additional length and more complicated head-walls.

174. — When located square across the road, the *length* of a culvert depends upon the width of roadway and the depth of fill over it. Whatever the depth of fill, the culvert must be long enuf to accommodate its side-slopes.

This slope can usually be taken as $1\frac{1}{2}$ to 1. This means that for every foot of rise the bank goes outward $1\frac{1}{2}$ ft. Therefore, for a 10-ft. fill over the top of a culvert, the roadway to be 16 ft. wide, the length of the culvert between parapets or head-walls will be $2 \times 1\frac{1}{2} \times 10 + 16 = 46$ ft.

This length, it will be noticed, is irrespective of the height or area of waterway, and the wings, whatever their design, will extend beyond this. The length of wing-walls will be about equal to the span, but will be governed principally by the local conditions.

Where the road is unimproved or has not been graded as thoroly as will be necessary in succeeding years, probable changes in grade or alinement should be estimated and the culvert located to fit them. This is very important if a permanent culvert is to be used. It is folly to build a concrete culvert so short or in such a position that when the road is improved it must be rebuilt.

175. Foundations. — Upon the culvert's foundation depends the stability of the whole structure. "Foundation" is here used to indicate the natural bed of soil, carrying footing for bridge abutments or the walls of a culvert. The amount of attention demanded varies with the size and importance of the structure, upon the loads it is to carry, and upon its type.

No part of bridge construction requires more care and skill than determining the proper treatment of the foundation and the construction of footings. A soft foundation may be improved by compacting or by spreading over it a layer of sand or gravel from 12 to 18 inches thick.

176. Bearing Power. — Different foundations, ranging from hard rock to the light loam soil of prairie country, will be met, and these vary greatly in their bearing or supporting power. Good judgment and experience, aided by a careful study of the soil in question, should enable the practical man to estimate its supporting power with a reasonable degree of accuracy.

Safe loads, as given by Baker, a leading authority, are as follows:

	Supporting Power in Tons per sq. ft.
Rock — in thick layers, in natural bed	200
Clay — in thick beds, always dry	4
Clay — in thick beds, moderately dry	2
Clay — soft	1
Gravel and coarse sand, well cemented	8
Sand — Compact and well cemented	4
Sand — clean and dry	2
Quicksand, loam soils	0.5

177. — The area of the base of a wall or footing must be sufficient so that the load will not exceed the values given in the table. The footing may be broadened to secure this or it may rest upon a timber platform or piles.

For small concrete structures resting on ordinary, moderately dry soil, it is generally sufficient to spread the concrete footing, precautions being taken to prevent scour in a soil which washes badly. If the foundation is soft, as often happens in marshy or swampy sections, additional support for the footing is necessary for heavy structures. Frequently this is of wood, as described in §§ 179 and 181.

178. Paving. — Culverts may be built with or without a floor, depending upon the stability of the soil at that point. A smooth paving, such as concrete, increases the discharging capacity of the culvert, and prevents to a great extent clogging by drift. It also prevents cutting of the stream-bed and undermining the foundations. Joints should be provided between the floor and sides of the culvert to protect the

floor from cracking in case the walls settle. In some cases, however, the floor is made sufficiently strong and heavy and carried clear across the whole structure, when of course, the side walls rest upon it.

To prevent undercutting or erosion under the floor, which has ruined many otherwise good culverts, an apron or cut-off wall should in all cases be carried down to the bottom of the footing. This apron is a vertical wall not less than 6 inches thick, located at the up-stream edge of the floor, but may sometimes be necessary at the downstream end also. The floor is frequently carried out to the end of the wing-walls, improving the smooth waterway, and giving added protection to the wing. But if the bottom, considered with relation to the slopes and stream-velocities will warrant it, the floor may be entirely omitted.

179. Pile Foundations. — Occasionally, for more important structures, and when the foundation is especially soft and wet, it will be necessary to use piles. They should be driven close together, say two to three feet apart both ways, sawed-off below water level, and a timber platform built on them, or a bed of concrete deposited around their tops, if conditions are favorable. The number to be used is usually determined by computing the safe bearing power in terms of the hammer's weight, drop, penetration, etc., but for small jobs, a more certain way is by making test-loadings on individual piles.

Piles should be 10 to 12 inches in diameter at the butt, and not less than 6 inches at the point, if of a length of 15 ft. or upward, and proportionately less if shorter. In driving, an iron hoop should be used at the top to prevent splitting and brooming. Ordinary pine piles will cost from 12 cents to 20 cents per lineal foot delivered at the job in most sections. In ordinary soil the cost of driving short foundation piles should not exceed $1 each.

Short piles are sometimes driven to compress and consolidate the ground over a considerable area, thus to increase its bearing power, but usually this result is more economically attained by means of sand piles, perhaps combined with sand or cinder filling on top.

180. When Called For. — Piles are used in foundation construction under two typical conditions; first, when the piles are driven thru soft or fluid material; second, when no hard bottom can be reached by any reasonable length of pile and "skin-friction" with the ground is sufficient to support the load with safety.

In the first case, the pile receives little if any lateral support and therefore acts as a column; while in the second case, the true pile action occurs and the load is limited by the adhesion of the ground to the surface of the pile.

Piles located in streams often have to resist lateral forces due to the impact of drift, ice, etc. Such forces should be provided for if practicable by "sway" or lateral bracing.

Timber piles are also extensively employed in culvert construction and maintenance, as temporary structures until the filling-in of embankments, or more permanent culverts of steel or concrete can be built to replace them, or until they are reconstructed of the same material. An extended discussion of pile foundations is beyond the scope of this course.

181. Timber Footings. — A log or plank platform will sometimes serve to distribute the pressure and tends to prevent uneven settlement of the footing or tipping of the abutments, but should only be used where it will be continually wet. Thus, two 6 x 6 timbers running lengthwise of the culvert, covered with short lengths of 4-inch plank, have been used, or 10-inch or 12-inch logs, notched and laid similarly.

182. Cofferdams. — When foundations must be prepared under water, a cofferdam is generally necessary within which the footing is built. A cofferdam is a water-tight wall, sometimes of earth, but usually of timber or a combination of these two materials, built to enclose a proposed foundation. After constructing a cofferdam around the site and pumping out the water, the foundation is prepared by driving piles or otherwise, when laying the masonry may proceed. A cofferdam is most useful only where the stream bottom is nearly impervious, for if there is an excessive leakage of water it will be impossible, or at least very expensive, to pump it out.

The difficulties in using the cofferdam method increase

It wasn't necessary to have an engineer, the Commissioners said.

They *called* it concrete in both instances. Question: Would proper engineering control have been worth while?

rapidly with the depth of the water. If deep or the current swift, cofferdams are very expensive and the construction of each is a separate problem to be attempted only under the direction of a competent engineer. However, for small culverts and bridges, the water seldom exceeds 6 ft. in depth, and with a mud bottom, free from boulders, there should be little difficulty in constructing cofferdams, by using a single or double row of sharpened plank fastened to a waling-strip or guide timber.

If the bottom is good and the puddle wall (often made by depositing clay outside the plank wall) carefully built, a small hand pump, set in a small sump in one corner, will generally keep the bottom sufficiently dry. If the bottom is sandy or gravelly a gasoline bilge pump will be useful.

183. — If the foundation is solid rock and there is no current the *concrete* may be deposited *in bags* until the water level is reached, no cofferdam being necessary. Means must be provided however to insure that the bags are regularly and evenly placed, like stone in a wall, so they may adequately support the structure placed on it.

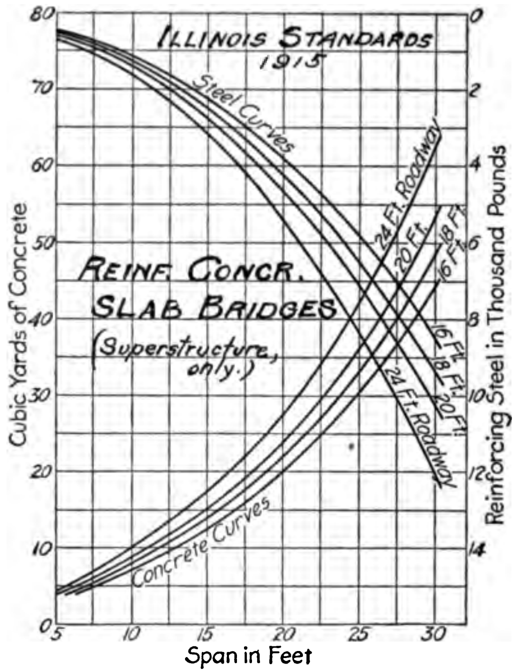
184. Dry Foundations. — For a rock foundation, it is generally enuf to cut away the loose and decayed portions and prepare a surface as nearly as possible at right angles to the direction of the pressure. For other foundations, it is necessary to see that the footings are below the frost line, in cold climates, and that the foundation has sufficient area proportioned to the bearing power of the soil to sustain the loads coming upon it. Moreover, in soils of any character, the abutments must be protected against undermining by currents of water.

If structures are located in soft or swampy ground, where it is impossible to secure a firm, natural foundation, special forms of foundations may be necessary such as "spread footings" or reinforced concrete floors which distribute the weight over a great area. In instances of this kind, each case must be taken as a separate engineering problem. Knowledge of the best methods can only come with experience, or thru the guidance of a skillful engineer.

185. Elements of Destruction. — The foundation selected must be able to carry the load upon it permanently. The

main factors which tend to destroy its permanency are: (*a*) Scour in the bottom, undermining the footings; (*b*) frost, and (*c*) undermining of the outlet.

1. Bottom scour may be prevented by a stone pavement from about 6 to 12 inches in thickness, or by using a thin pavement of concrete about 6 inches thick. Carrying the footing across the entire bottom of the culvert distributes the load and prevents scour. In larger structures, a cut-off wall across the channel at the upstream end is often used. When no provision is made to prevent scour the side walls should extend not less than 18 inches below the bed of the stream.

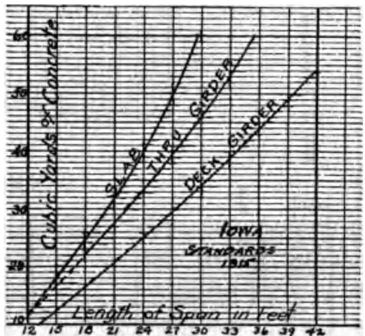


2. Frost, while a serious matter farther north, seldom penetrates deeper than 6 inches in this State. Any footing here carried below the surface of the ground 12 inches is probably safe from frost.

3. Undermining at the outlet is generally caused by water dropping some distance at the end, or by the increased velocity of the water due to passing thru the culvert. This may be prevented by paving the outlet with stone, or concrete, or by a baffle-wall built just below the outlet to form a basin.

186. Small Bridge Types. — Concrete bridges may be classified as slab, girder, and arches. Slab and girder bridges or culverts are those in which the pressure from the bridge floor

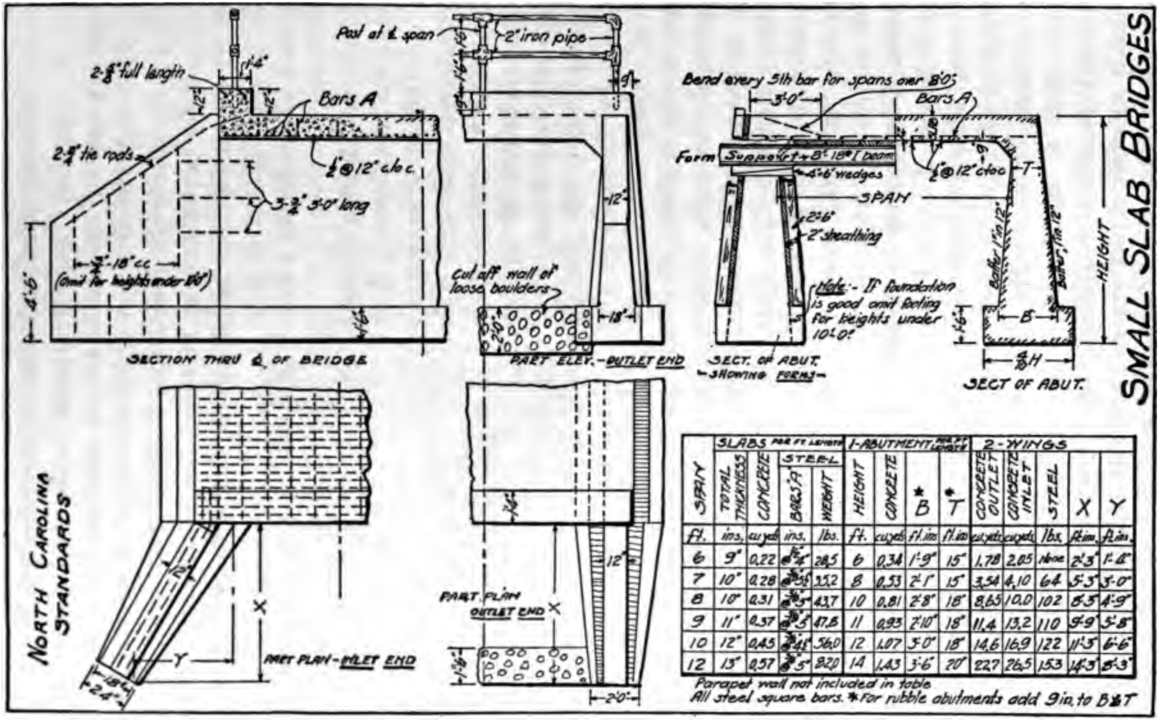
acts vertically upon the abutments. They consist either of flat slabs of reinforced concrete, or of combined beams and slabs of concrete, both reinforced with steel. Since arch bridges are curved, the pressure upon the supports is not vertical. Flat slab construction is suitable in level countries and for locations where the foundation is of soft material. Arches are especially economical in localities where the roads can be built at a considerable height above the streams and where there is rock, gravel or similar hard soils offering a solid foundation.



Comparison of Quantities in Reinforced Concr. Bridges

A flat slab bridge consists essentially of a concrete floor of uniform thickness strengthened with steel rods resting upon vertical abutments. The rods in the slab which run lengthwise of the roadway take up tension stresses due to loads on the bridge, while rods at right angles to the roadway distribute the load and reinforce against temperature stresses. The distance from the bottom of the slab to the top of the footing varies to meet the requirements of the waterway. The quantities of materials, and hence the approximate costs of slab bridges may be arrived at from the diagrams herewith, based upon Illinois, North Carolina, and Iowa standards, respectively.

186a. Permanency in Concrete Work. — Before the general establishment of State Highway Commissions it was difficult to secure adequate supervision of the design and construction of highway bridges, — vastly more than with railroad bridges, for obvious reasons. The demand for heavier loading, together with a considerable degree of standardization made possible thru such Departments, have, however, begun to result in much superior structures to those constructed by counties, even where the more progressive ones had pretty generally adopted the use of concrete.



SPAN	SLABS PER FT. LENGTH: TOTAL THICKNESS	SLABS: CONCRETE	SLABS: STEEL: BARS "A"	SLABS: STEEL: WEIGHT	1-ABUTMENT PER FT. LENGTH: HEIGHT	1-ABUTMENT: CONCRETE	1-ABUTMENT: B*	1-ABUTMENT: T*	2-WINGS: CONCRETE OUTLET	2-WINGS: CONCRETE INLET	2-WINGS: STEEL	2-WINGS: X	2-WINGS: Y
ft.	ins.	cu. yds.	ins.	lbs.	ft.	cu. yds.	ft. ins.	ft. ins.	cu. yds.	cu. yds.	lbs.	ft. ins.	ft. ins.
6	9"	0.22	5/16"@4"	28.5	6	0.34	1'-9"	15"	1.78	2.05	None	2'-3"	1'-8"
7	10"	0.28	3/8"@5½"	35.2	8	0.53	2'-1"	15"	3.54	4.10	64	5'-3"	3'-0"
8	10"	0.31	3/8"@5"	43.7	10	0.81	2'-8"	18"	8.65	10.0	102	8'-5"	4'-9"
9	11"	0.37	3/8"@5"	47.8	11	0.93	2'-10"	18"	11.4	13.2	110	9'-9"	5'-8"
10	12"	0.45	3/8"@4½"	56.0	12	1.07	3'-0"	18"	14.6	16.9	122	11'-5"	6'-6"
12	13"	0.57	3/8"@5"	82.0	14	1.43	3'-6"	20"	22.7	26.5	153	14'-3"	8'-3"

Parapet wall not included in table
All steel square bars. *For rubble abutments add 9 in. to B & T

To show the dangers attendant upon the injudicious use of even good materials, the Iowa Commission, early in 1915, made a detailed study of eighty-two concrete bridges and culverts, all built under county control. The first step was a physical examination of each structure; measurements were made, foundations exposed, photografs taken, and a detailed record made of every evidence of failure either in design or construction. They found 20 per cent unsafe for traffic; 73 per cent had clearly developed defects; 3 per cent had collapsed entirely.

The defective and *unsafe conditions* were attributed to the following causes: Insufficient foundation areas, or depths, or both, 48 per cent; inadequate reinforcement, 20 per cent; insufficient dimensions of sections, 8 per cent; "thin-section" members in positions subject to severe frost action and stream erosion, 36 per cent; inadequate wing-wall lengths, permitting erosion back of them, 10 per cent; inferior materials and workmanship, 10 per cent. Thirty-four per cent needed immediate repairs or renewals. Summarizing, 65 per cent were in distinctly bad condition due to defective foundations, and whereas the State specifications limited the loading upon clay soils to 2 tons per sq. ft., the loads on many of the structures examined reached 8 tons per sq. ft.

CONCRETE

187. Use of Concrete. — First-class concrete structures, wisely designed, are without doubt the best to use for road work in point of durability and cost of maintenance. This is particularly true for culverts whose opening is greater than that of a 24-inch pipe. For them concrete should be adopted as the standard. Various types of concrete pipes are on the market which can be made in all sizes, and these can be used satisfactorily. Townships having local supplies of good concrete materials could make this pipe themselves. Collapsible forms for this purpose can be readily bought or made.

188. Selecting the Aggregate. — The materials such as sand, crushed stone or gravel which are mixed with cement to form concrete are called the "aggregate," and careful selection is necessary to obtain good concrete. The aggregate must be clean, coarse, hard, and well-graded in sizes. It must be *clean*, because if the separate pieces are coated with fine dust or clay, the cement can not form a satisfactory bond with them; *coarse*, because a coarse aggregate presents a smaller total surface for the same volume of mineral than if in smaller sizes. It thus makes a stronger concrete with the same amount of cement.

Concrete is no stronger than its aggregate, or the bond of the cement uniting it, consequently the aggregate must be

and remain strong and hard under all weather conditions. Some sands and gravel contain pieces of shale, or soft particles, which, after a short exposure to the weather, soften and go to pieces. Chalky, or other soft stones can not be expected to give good results when used for concrete.

189. Sizes in Aggregate. — When deposits of good gravel can be found they are a source of great saving, and furnish excellent concrete if intelligently used. There is great danger, however, that since there are very great and accidental variations in the sizes of materials from different parts of the same bed, or between different beds, that the important effects of such variation will be overlooked. This is because the putting together of aggregates in proportions bearing a definite relation to their sizes is a matter which vitally affects the strength, density, durability, and ultimate economy of the concrete structure.

Early in 1915, the Engineering Experiment Station of Ames, Iowa, published the following results of *compression tests* of fifty concrete cylinders, 8 inches × 16 inches, twelve days old, made of gravel with varying amounts of sand, as shown, and with the average density of the mixtures varying from 68 to 79 per cent. Note that the poorest 1:5 mixture, meaning one volume of cement to five equal volumes of natural gravel (No. 4 in the following table) gave a strength of 240 lbs. or only about one-eighth the strength of No. 5, which also had very nearly a 1:5 mixture. No. 5 however, had a 10 per cent greater density with only about half as much sand but about ten times as much coarse aggregate. Doubling the amount of cement, however, with about the same quantity of sand, as in No. 8, only increased the strength about 25 per cent, showing again that the cheapest and best concrete was made, in these cases, from some such mixture as No. 1 or No. 5, both of which show highest density and best *gradation of sizes.*

STRENGTH OF GRAVEL CONCRETE CONTAINING VARIOUS PROPORTIONS OF SAND TO COARSE AGGREGATE.

Specimen No.	Per cent sand to coarse aggregate	Proportions	Density	Strength, lbs., per sq. in.
1	40	1:5 (1:2:3)	0.789	1,600
2	55	1:5 (1:2¾:2¼)	0.770	1,200
3	75	1:5 (1:3¾:1¼)	0.737	800
4	95	1:5 (1:4¾:¼)	0.680	240
5	42	1:4¾ (1:2:2¾)	0.784	1,872
6	55	1:3¾ (1:2:1¾)	0.775	1,792
7	75	1:2⅔ (1:2:⅔)	0.709	2,120
8	95	1:2 1/10 (1:2:1/10)	0.712	2,360

Broken Stone. The aggregate of broken stone should also be well graded in sizes, since the strongest concrete has the greatest density. There should be such quantities of the various sizes from fine to coarse that the total *voids* or empty spaces between the pieces is the least possible. This is often and simply determined in an experimental way by filling a bucket with the aggregate and observing how much water can be put into the bucket besides. By changing the proportions of the stone, sand, or gravel, the combination giving the greatest density can be pretty accurately found. Concrete made in these proportions will not only be stronger, but also cheaper, since less cement will be required to give equally good results as where more cement and a less carefully graded aggregate is used.

190. — The mixing, as suggested elsewhere, is just as important as any other part of the process of making concrete. In fact good concrete is the result of everything being *right,* and no step in the process nor quality in any of the materials can be otherwise and get that result. Most people do not realize these facts. With a proper aggregate, the aim of proper mixing is to insure that as nearly as possible every particle of sand will be coated with cement, and every piece of stone or gravel will be floating in mortar, thus reducing the voids in the whole mass to the lowest possible minimum.

191. Quantities. — Estimates of concrete materials needed for a given amount of concrete may be based on the following table. Note that one barrel equals four bags of cement.

192. Concrete Forms. — The cost of concrete bridge and culvert work is largely influenced by the cost of the forms. The average carpenter, inexperienced in this class of construction, is likely, unless properly directed, to greatly increase the cost. He may use too many nails, increasing the cost of removal, and spoiling a large amount of lumber for further use. It is a good rule to avoid the use of nails whenever possible. Then too, an inexperienced man will hardly realize the enormous weight the forms must carry, and failing to make the centering sufficiently strong, allows it to bulge and sag. Any slight settlement of the forms occurring after the concrete has

Amount of Cement, Sand and Stone required per Cubic Yard of Rammed Concrete with various Mixtures.

Mixtures			Amounts			Mixtures			Amounts		
Cement	Sand	Stone	Cement bbls.	Sand cu. yds.	Stone cu. yds.	Cement	Sand	Stone	Cement bbls.	Sand cu. yds.	Stone cu. yds.
Stone 2½ inches			Most Small Stones Screened Out			Stone 1 inch and under			Dust Screened Out		
1	2.0	4.0	1.53	.47	.93	1	2.0	4.0	1.46	.44	.89
1	2.5	5.0	1.26	.48	.96	1	2.5	5.0	1.19	.46	.91
1	3.0	5.0	1.17	.54	.89	1	3.0	5.0	1.11	.51	.85
1	3.0	6.0	1.06	.48	.97	1	3.0	6.0	1.01	.46	.92
1	3.0	7.0	.94	.42	1.05	1	3.0	7.0	.91	.42	.97
1	4.0	7.0	.87	.53	.93	1	4.0	7.0	.83	.51	.89
1	4.0	8.0	.81	.49	.98	1	4.0	8.0	.77	.47	.93
Stone 2½ inches and under			Dust Screened Out			Gravel ¾ inch and under			Sand Screened Out		
1	2.0	4.0	1.48	.45	.90	1	2.0	4.0	1.34	.41	.81
1	2.5	5.0	1.21	.46	.92	1	2.5	5.0	1.10	.42	.83
1	3.0	5.0	1.14	.52	.87	1	3.0	5.0	1.03	.47	.78
1	3.0	6.0	1.02	.47	.93	1	3.0	.60	.92	.42	.84
1	3.0	7.0	.92	.42	.98	1	3.0	7.0	.84	.38	.89
1	4.0	7.0	.84	.51	.90	1	4.0	7.0	.77	.47	.81
1	4.0	8.0	.78	.48	.95	1	4.0	8.0	.71	.43	.86

been deposited and before it has hardened sufficiently to sustain its own weight, is, of course, extremely detrimental to the structure. In fact this is often the beginning of destruction thru incipient cracks thus formed.

Improper bracing may cause much loss of time and unsightly work. Many braces can be omitted by using bolts or wires. This applies particularly to forms of abutments and wing-walls where opposite sides can be tied together, causing one form to help hold the opposite form in place, provided the first is properly secured in *its* position.

Proper methods of form construction and careful handling will save much lumber and may allow the forms to be used several times. Where possible, they should be held in place by hardwood wedges, well fitted and carefully driven. If the forms are supported upon a muddy creek bottom, for example,

it is necessary to place them on a firm foundation as any settlement strains on the new concrete must be avoided.

The face forms should be made of 2-inch lumber, sound and free from knot-holes or other defects, constructed so that they will be held rigidly in place. Where knot holes are unavoidable, they should be plugged with damp clay immediately before filling, or covered with a small piece of tin or building paper on the inside of the form. The inner face and both edges of the lumber should be dressed to insure a smooth finish on the exposed face of the concrete and prevent the ridges due to uneven thickness of lumber. It is impossible to fit undressed edges of boards closely together. This permits the cement mortar to leak through the cracks, and forms unsightly ridges on the finished faces. The forms should be cleaned carefully, and just before using again, it is well to paint the inside of the form with soft soap, paraffine, or crude oil to prevent the mortar from sticking.

193. Removal of Forms. — Weather conditions decidedly affect the rate at which concrete hardens, and directly influence the time required before the forms can be removed. In the cool weather of spring and fall, concrete hardens slowly, so that the forms may need to remain two to four or more weeks. Even in summer, during cool and cloudy weather, forms should not be removed for several days, say ten or twelve, and should remain longer, if practicable.

Under the most favorable weather and construction conditions, no forms should be "stripped" within less than forty-eight hours after depositing the concrete. This applies to those forms which give side-support only, i.e., those which carry *no* loads. For arches and floor slabs the supporting forms must remain much longer than for the end and wing walls, say at least twenty-eight days. Removing forms too soon has been the cause of more accidents than any other one thing. It is sometimes required that before removing the form, the concrete in slabs and arches shall be sufficiently hard to cause a 20-penny spike driven into the concrete to double before it has penetrated one inch.

194. Placing the Steel. — When the forms have been erected and carefully measured to insure that everything is true and

to line, the steel is to be placed. In doing this it is necessary to follow the design strictly and make certain that pieces of the proper size are placed exactly as planned and carefully wired into position. Workmen are apt to be careless in placing the steel and neglect wiring the rods together because it is a little tedious. Too much care cannot be exercised in this work, for while a rod in its proper position performs an important function in giving strength and stability to a structure, if allowed to shift a short distance it may be absolutely worthless, leaving this part of the structure proportionately weaker than it was planned to be.

The steel must be free from grease, dirt, excessive rust or scales when placed, because the presence of any of these prevents the concrete from properly bonding to it. After the steel is placed, all dust and dirt should be removed from the forms and their interior thoroly wetted before pouring the concrete, unless they are coated with oil or soap as already suggested.

195. Mixing Concrete. — Mixing may be done either by hand or machine. The method employed is determined principally by the size of the job. If the amount of concrete is small, hand-mixing is more economical, while for large jobs machine mixers are better and generally cheaper, tho if the machine must be frequently moved, hand-mixing may prove cheaper. A better and more uniform concrete can be made with a good machine than by hand. Its type should be such as to insure a thoro and uniform mixing of the materials. The strength of the concrete will be greatly increased if the mixing is continued for three or more minutes even in a mixer running at regular speed. Most contractors are unwilling to do this, or are unaware of the advantage to be gained in this way. The extra cost of very thoro mixing, however, is vastly more than made up for by the added strength of the product.

Enuf water should be used to make the concrete of mushy consistency, requiring very little tamping to bring the mortar freely to the surface. This mushiness, however, is more affected by proper proportioning of the aggregate than to the quantity of water used. For example, to add water continually to concrete containing an excess of coarse stone is positively the worst

thing that can be done to it. But if the stone runs in graded sizes, and the sand does also, smooth-working, mushy, strong, and perfect concrete is practically unavoidable, providing water and cement in at least reasonable proportions is supplied to it. The water must be reasonably clean. Concrete otherwise good has been spoiled, and was required to be removed because extremely muddy water was used.

196. Hand-Mixing. — If hand-mixing is employed it should be carefully done upon a tight board platform, and should be subjected to thoro supervision. The following directions from Taylor & Thompson, leading concrete authorities, will be found useful when needed.

Assume a gang with four men to wheel and mix the concrete, two to place and ram it. When starting a batch, two mixers shovel or wheel sand into the measuring box or barrel — which should have no bottom or top — level it and lift off the measure, leveling the sand still further if necessary. They then empty the cement on top of the sand, level it to a layer of even thickness, say a total of six inches, and turn the dry sand and cement with shovels three times (as described) or until the mixture has a uniform color. While these two men are mixing sand and cement, the other two fill the gravel (or stone) measure about half full, then the first two take hold with them, completely filling it. The gravel measure is lifted, the gravel hollowed-out slightly in the center, and the mixture of sand and cement is shoveled on top, making a layer of nearly even thickness. A definite number of pails are filled with water and poured directly on the top of these layers, giving greater uniformity of the product than by adding the water directly from a hose. After soaking in slightly, the mass is ready for turning.

Two men, A and B, with square-pointed shovels, stand facing each other at one end of the pile to be turned, one working right-handed, the other left-handed. Each man pushes his shovel along the platform under the pile, lifts the shovelful, half turns with it, and turning the shovel completely over with a spreading motion, draws the shovel toward himself. He thus deposits the material about 2 ft. from its original position, thoroly "chopping" and mixing it with downward thrusts of the shovel after having turned it on the board. This operation forms a flat ridge alongside the original pile, flat enuf so the stones will not roll down. As soon as, but not before, a single ridge is complete, two other men, C and D, start turning it for the second time, and again form a flat ridge, and finally a level pile. A third mixing is similarly done.

The quantity of water used must vary with the moisture in the materials used, and the final consistency required. It is advisable for an inexperienced gang to use an excess of water. The rule is to use as much water as can be thoroly incorporated. Such concrete will be soft and "mushy" and fall off the shovel unless handled quickly.

After the material has been turned twice, as described, and the third turning commenced, two of the mixers who have finished turning may load the concrete into barrows and wheel it to place. After the mass has had the third turn by the other two men, they start filling the gravel-measure for the next batch.

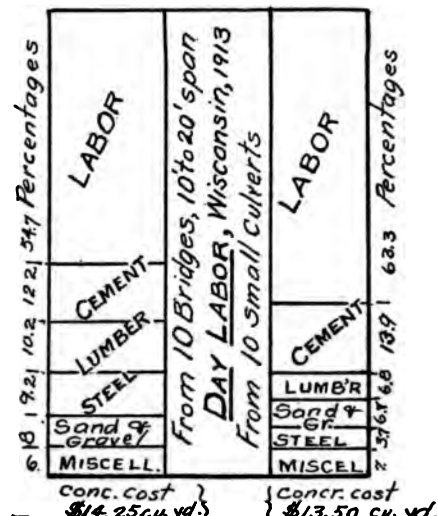
If the concrete is not wheeled over 50 ft., four experienced men ought to mix and wheel on the average about 10½ batches of 4/5 of a cubic yard each in ten hours. This is based on the proportions of 1:2½:5 and assumes that a batch consists of one barrel (4 bags) Portland cement, 9.5 cu. ft. of sand, and 19 cu. ft. of gravel or stone. This is the simplest kind of concreting and makes no allowance for the labor of supplying materials to the mixing platform, or for building forms." At $2 per day this is a cost of about $1 per cubic yard for hand-mixing.

197. Placing the Concrete. — The concrete should be carefully placed without separating the aggregate and mortar. The mass of concrete in the forms should be kept practically level, otherwise the water will drain from the high places, carrying part of the cement with it. The concrete should be moderately tamped, and the face "spaded" thoroly with a flat-faced tool to force back the coarser aggregate and bring the mortar to the form. A fair tool can be made from a hardwood board about 1 x 4 inches, its end sharpened to a chisel edge, on one side only. In use, the flat side is placed against the form, and a smooth finish upon the exposed surfaces depends upon the care with which this spading is done.

The mixture should be quite plastic, as a dry one has no tendency to flow and fill the forms perfectly. Concrete in abutments should be laid in continuous horizontal layers, thus avoiding any continuous vertical joints. In floor slabs, the concrete should be placed to the full thickness of the slab at one time, and vertical joints made in the center of the slab if the entire job can not be completed without interruption. If impossible to build the abutments in continuous horizontal layers, it is best to divide the work into sections and place each without interruption. This requires some provision for vertical joints. To key the abutment-sections together a deep and massive groove may be formed (it should have suitable reinforcement), using the temporary partition in the form as a support for the dovetail-making arrangement. The timber used for this purpose will need to be slightly wedge-shaped, else it can not be removed without destroying the groove.

198. Costs: Day Labor. — Where concrete work is done by day-labor, or force account, as engineers frequently term it, it will often be useful to know about what proportions the various items of cost bear to the total. Commissioners will

find this specially useful for checking purposes against claims for labor and materials presented to them on culvert work. Wisconsin, in 1913, gathered such data on twenty small bridges and culverts. The results are shown by the diagram herewith. The variance in proportions of cost is of considerable interest, and upon reflection, is easily understood. The total money-cost per cubic yard will, of course, vary with labor and material prices.



PROPORTION of VARIOUS ITEMS TO TOTAL COST Reinf. Conc. Br. & Culverts

199. Laying Concrete in Water. — Only in exceptional cases should concrete be placed in water. Then the greatest care must be exercised to prevent the fresh cement from being washed out. Under no circumstances should it be *thrown* into or placed in the water with shovels, or deposited in running water. In small jobs, the concrete is sometimes deposited in open-weave bags, or it may be placed in buckets with a board covering it while it is lowered carefully to the bottom. Then the bucket or pail is carefully overturned, and the board withdrawn, and the bucket gently raised, allowing the concrete to flow out. The water must not be agitated, nor the concrete disturbed before it has taken its initial set, usually from four to eight hours. In large jobs, the concrete is sometimes placed by means of a tube extending into the water, with its lower end near the bottom. This is called a "tremie." By keeping a continuous flow of concrete passing thru the tube, the cement can not separate from the aggregate.

200. Slab Bridges. — As already stated, slab bridges consist either of plain, flat slabs, resting on suitable abutments, or of combined beams and slabs of concrete both suitably reinforced with steel. For spans of 20 feet or less, plain slabs are most economical, more simple to build, and will, therefore, be the type chiefly considered here.

In prairie country stream gradients are usually flat, the water-course crooked, and the banks low. For such streams, where headroom is limited, the slab type of bridge or culvert is preferable to the arch. Here the foundation is usually of light soil, and rock, if present, is usually too deep to found abutments upon it. Under these conditions the slab bridge which carries the load vertically to the foundation is better than any form of arch, which carries its load into the soil at an angle. Also, the slab-bridge is less likely to suffer damage from any slight displacement or settlement of its abutments, while the least movement of an arch abutment endangers its stability. The figure reproduced herewith gives much valuable information.

201.— Slab-bridge *floor forms* are so simple in construction that no detailed description is necessary. One of the most important things is to prepare for the enormous weight which the forms will have to support. The floor-slab for a 20-ft. span with 16-ft. roadway will weigh approximately 25 tons. The supporting shores, braces, and "lagging," or form lumber, sustain this weight and must be designed accordingly. Where a muddy creek bottom is encountered, the shores and braces must rest on a firm foundation so no settlement will occur.

202. — The dimensions of the end and *wing walls* of culverts depend upon the clear vertical opening or height of bridge floor above the footing. This height is entirely independent of the span, but is influenced by local conditions at the bridge site. It depends upon the depth necessary to secure a firm and adequate foundation and the amount of headroom necessary to accommodate the stream flow. The footings must in all cases be carried to a foundation having sufficient bearing power, as described in § 176.

203. — The thickness of the floor slab required for the various spans, together with the size and spacing of the reinforcing rods, North Carolina standards may be found in the drawing on page 128.

Slab bridges and culverts should have a fill of at least 8 to 12 inches of road material over them. The use of a concrete floor without a covering of earth or other material is not to be recommended, as this blanket helps to distribute the load, and prevents wear, shock, and excessive vibration.

The CONCRETE for the slab should be proportioned as 1 sack of cement to 2 cu. ft. of sand and 4 of screened gravel or crushed stone. This is a very meager rule, however, since it takes no account of the sizes of materials. If stone is coarse, say $\frac{3}{4}$ inch to 2 inches in greatest dimension, and the sand fine, more of it will needed. But if the stone is relatively fine, and the sand coarse, more cement is needed to coat the area of the pieces, as already explained. A smooth, mushy concrete of maximum density is what should be constantly sought for, and variations from above proportions should be made to secure this result. (Note also, carefully, the discussion in § 189.)

204. Timber Culverts and Bridges. — In any timber structure it should be borne in mind that wherever wood is in contact with earth (except when always wet) it will decay rapidly. For this reason it is advisable to use heavier material at these points than is required for strength alone. If timber is the only material available, it may be advisable in some cases to creosote it, or otherwise specially treat it to resist decay. In salt or brackish water creosoted timber is practically necessary because of the attacks of marine wood-borers, such as the teredo worm.

205. Varieties of Wood. — White oak is the most durable lumber to use in road culverts. Red oak should be avoided, especially when in contact with earth. Wood should never be used for any waterways where a pipe can be used. Pitch pine free from large knots is durable and makes satisfactory floor joists. Rough sawed lumber should be used since there is a considerable loss in planing. Three-inch oak flooring should be used where the wear comes directly on the floor. Its durability is twice that of two-inch flooring, altho its cost is only one-third more, since flooring must be renewed when worn to an inch in thickness. Creosoted lumber is more durable than ordinary timber and when obtainable will cost about $45 per 1,000 ft. B. M.

Small Structures. — The ordinary type of small timber culverts consists usually of a mudsill or imbedded "post-abutment" in an earth bank with floor joists resting directly upon it. Failures may come from decay, from undermining of

the earth abutments or the floating off of the entire structure. Their use is to be avoided, if possible.

206. — The table below shows size and spacing of wooden floor joists for long span culverts, as used by North Carolina, using 3-inch flooring 16 ft. long.

Span	No. of Joists	Size	Length	Spacing	Total Ft. B. M. in Floor and Joists
8′	6	3″ × 12″	10′	3′0″	660
10′	7	3″ × 12″	12′	2′8″	828
12′	8	3″ × 12″	14′	2′3″	1008
14′	9	3″ × 12″	16′	2′0″	1200
16′	6	4″ × 16″	18′	3′0″	1440
18′	6	4″ × 16″	20′	3′0″	1600
20′	7	4″ × 16″	22′	2′8″	1877
24′	9	4″ × 16″	26′	2′0″	2500

When timber structures are used on a surfaced road the floor may be covered with the surfacing material where the span does not exceed 16 feet.

207. Pile Structures. — Pile bents with the piles driven to a suitable penetration, should be used in running water, or where the bottom is too soft to use a mudsill, or where a fill or masonry bridge is not practicable. The piles should be from 12 to 18 inches in diameter at the butt and not less than 6 inches at the point and should be driven to a good bearing. The tops should be sawed level and the cap bolted on and securely fastened. Not less than 4 piles should be used in a bent and it is well to "batter," or drive slanting, the outside piles if the water is deep or the current swift.

210. Size of Opening. — A culvert should be large enuf to provide for all ordinary rainfall which may come upon the area it drains. It is not generally advisable, on country roads, to make the size as great as would be required by the record-breaking rains which sometimes occur. Conservative engineers estimate that the damage occasioned by a washout once

in 15 or 20 years is not sufficient to offset the added cost of making the structure large enuf to care for the additional water.

No great refinement in the determination of the area of waterway is possible or necessary. The convenience and economy of the use of standard sizes and designs makes the problem one of determining which of several standard sizes will be more nearly satisfactory. For example, should a 24-inch pipe, which has an area of 3.14 square feet, be too small, the next size, a 30-inch pipe, would be used, which has an area of 4.92 square feet, or 56 per cent greater than the 24-inch. The same thing holds true with other types of waterways.

As a general rule it is well to make small culverts larger than the water to be provided for demands. They are subject to stoppage from accumulations of leaves and grass. To avoid this some road-builders make 15 inches a minimum diameter for pipe culverts.

211. — The two problems commonly arising are (*a*) To find the area of waterway for a new opening, or, more frequently, (*b*) To determine the size to use in replacing an old structure. The same elements are involved in both problems, but they are so indefinite that their consideration is merely an aid to the judgment. The principal elements involved are:

1. Rainfall. The ordinary maximum rainfall may be taken as varying from one inch to two inches per hour. However, the extent of this severe rainfall is usually limited to a few square miles. In the so-called cloud-bursts common to the West and Southwest, as much as 4 inches in a storm of less than an hour's duration is not very rare.

2. Area of Watershed. This is the total area draining into the waterway. For small culverts this area may be determined with sufficient accuracy by estimation, if the whole drainage area is in plain view, or by pacing the divides with a hand compass and roughly computing the area. For large culverts it may frequently be obtained from a map.

3. Shape and Slope of Watershed. When the drainage area is long and narrow and has a uniform slope, the water from the remoter parts will not reach the waterway until the water which falls near the culvert has passed thru. If, however, the

drainage area is more nearly circular or the watershed steep, most of the water may arrive at the culvert at substantially the same time.

4. Character of Vegetation and Soil. A heavy undergrowth or forest carpet will check the immediate run-off of the water, and a porous soil will absorb a large portion of an ordinary rain. But should a heavy rainfall come when the soil is thoroly saturated the total rainfall may rapidly reach the culvert.

5. Location and Design of Waterway. The slope of the culvert and condition of the channel above and below the ends will influence the capacity. The flow of a smaller size may be increased by permitting the water to dam up at the inlet. This is sometimes permissible with a pipe or a paved-bottom culvert, but should be avoided with other types.

There are two general methods of determining the required area of waterway: (1) By formulas, or rules; (2) By direct observation. Formulas should be used only as a check or guide to the judgment. They are commonly disregarded altogether in replacing an old culvert or where the needed area may be determined by direct observation. In the following table a few examples are given of results obtained by using a well-known rule.

212. AREA OF WATERWAYS

Drainage Area (Acres)	Very Mountainous (Sq. Ft.)	Hilly (Sq. Ft.)	Gently Rolling (Sq. Ft.)	Prairie (Sq. Ft.)
10	3.7	1.9	1.1	0.9
20	6.3	3.2	1.9	1.6
30	8.5	4.3	2.7	2.1
50	12.5	6.3	3.8	3.1
100	21.1	10.5	6.3	5.3
200	35.6	17.7	10.6	8.9
300	48.1	24.0	14.4	12.0
500	70.4	35.2	21.1	17.6
650	85.8	42.9	25.7	21.4

Thus if 200 acres are to be drained in the mountains, 35.6 sq. ft. of waterway is required, or say 6 x 6 box culvert. In gently rolling country a 3 x 4 will be seen to be of ample size. The Santa Fé Railway uses values ten to fifteen per cent greater than those in the first column.

2. Direct Observation. This is the most satisfactory method of determining the size of opening to use. Highwater marks should be ascertained from people in the locality, and the area of cross-section measured at a point where the stream is narrow and the banks steep. If the velocity at this contracted point in the stream can also be obtained, as by floats during high water, then a close estimate of the flood flow is possible, and the culvert size fixed with considerable accuracy. The culvert or bridge opening should have approximately the same area as that measured. Sluggish or tidal streams, such as exist near the coast, may be narrowed considerably. On the other hand, mountain ravines should have a larger opening than the appearance of the banks would seem to warrant.

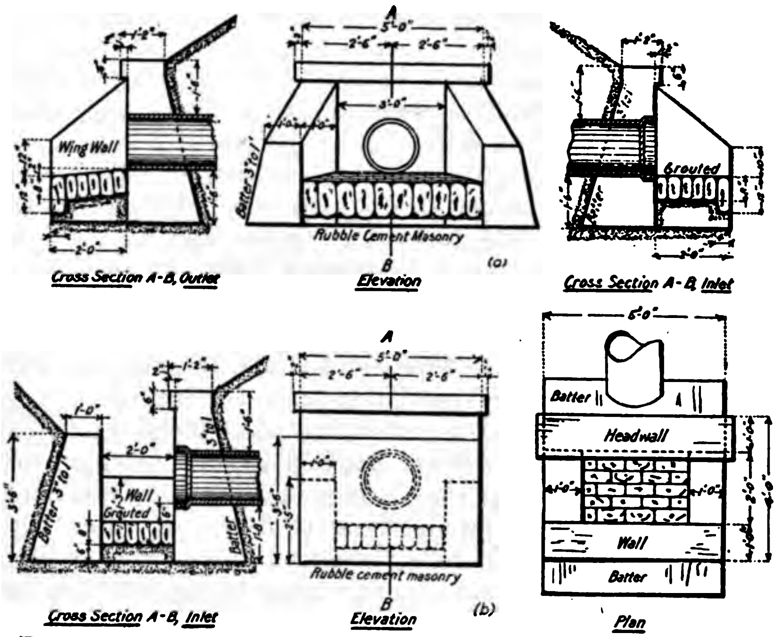
213. Pipe Culverts. — Pipe culverts are generally circular in cross-section and vary from 8 to 48 inches in diameter. They are made of vitrified clay, corrugated sheet metal, cast iron and concrete. Their circular shape gives great strength for the amount of material used, a large discharge, and provides a non-eroding surface for the water to flow along. But they require a greater height for a given area of waterway than a square or rectangular box and they must be carefully laid on an even slope.

Pipes smaller than 12 inches in diameter are in danger of stoppage by trash and mud, and unless a good fall is obtained (say 1 ft. in 20 ft.) they should not be less than 15 inches in diameter. Some road builders even advocate that 18 inches should be the least diameter used unless a catch-basin is provided at the upper end.

Pipe culverts are usually laid in sections or joints varying in length from 2 to 3 feet for vitrified pipe, to 12 feet for cast-iron pipe. The whole pipe should act as a solid piece and retain an even slope from end to end. The foundation under the pipe must be solid, and the joints must be tight and strong.

In ordinary clay or loam soil, if care is used in trimming the bottom of the trench for the pipe so that the earth directly under the pipe is not disturbed, the foundation will be satisfactory. If it is necessary to fill any part of the trench, the earth should be thoroly tamped before laying the pipe.

In swampy or other uncertain soils, where the weight of the



PIPE CULVERT ENDS — Top, Standard Type
Bottom, Inlet. flow from both directions

fill or other loads which may come on the pipe may cause it to settle in the middle, a pipe having as few joints as possible should be used. The foundation may be improved: (1) by excavating the bottom of the trench at least 6 inches below the bottom of the pipe and filling it with sand or cinder, if such material be available; or (2) a support of concrete or stone may be placed under each joint. Where this is necessary the pipe should be made of cast iron or corrugated sheet metal.

In filling-in the trench around the pipe, the earth should be carefully tamped in thin layers until the pipe is at least half covered, especially if it is clay pipe. Care should be used to make the trench wide enuf to allow tamping under the pipe. Too much fall is dangerous since it tends to cause erosion at the outlet. Too little fall reduces the discharge, allows sediment to deposit and permits water to stand, the continual freezing of which may completely close and in some cases destroy the pipe.

214. Headwalls for Pipe Culverts. — As a general rule the ends of pipe culverts should be protected by end walls. This protection is especially necessary for pipes laid in short sections. For long sections it is not so important, but it will usually be found that the saving in length of pipe will very nearly offset the cost of the headwalls and the culvert is more substantial with them. End walls commonly used are straight, but have wings at the upper end.

The straight-wall type is generally cheapest and most satisfactory when the diameter of the pipe is less than 36 inches. For diameters greater than 36 inches the flared wing type contains less material and the parapet wall is much shorter, lessening the liability of wash around the ends. The straight-wing type is common at the outlet end of the pipe and the flared-wing type at the inlet end. The cut herewith also shows a specially good type of inlet where the water comes from both directions alongside the road. Headwalls may be built of concrete, stone or brick.

215. Vitrified Pipe. — The use of vitrified clay pipe is limited to places where at least 12 inches of earth may be secured above its top, where a solid bed may be obtained and, if the winters are cold enuf, the fall is sufficient to prevent the possibility of water standing and freezing in it. Many failures have resulted from attempting to use this type of culvert when these conditions did not exist. If conditions are favorable, however, the culvert will be very durable.

The relative advantages and disadvantages of vitrified pipe for culverts may be briefly summarized:

Advantages	Disadvantages
1. Low in first cost. 2. Desirable in that it will not rust or decay. 3. Quickly laid.	1. Requires a heavy earth protection. 2. Has little supporting strength. 3. Requires headwall under all conditions.

216. Iron Pipe. — The chief use of cast-iron pipe for culverts is where the earth cover is so small that vitrified pipe would not be safe, as in some ditch crossings, or road intersections, where the foundation is too poor to use an easily broken pipe. Corrugated metal pipe serves the same purpose, is less durable, and is somewhat cheaper.

Corrugated Metal Pipe. — Corrugated metal pipe is made of thin, corrugated sheets of steel or iron bent and riveted in round and half-round sections. The corrugation gives it great strength for the amount of metal used, its strength, when the metal is the proper gauge, being sufficient to support any load which may ordinarily pass over the road. The metal used is very thin and, should the protecting coat of galvanizing be destroyed, is likely to rust away rapidly. This type of culvert has been in use only a few years, not long enuf to determine its durability. Manufacturers claim a life of from 15 to 25 years. It is probable, however, that the life is largely dependent upon the type of soil in which it is laid. If laid in a damp soil containing a large amount of organic matter, the action of organic acids will probably cause it to rust out within 10 years. On the other hand, if laid in a dry, loam soil, its life should greatly exceed this.

Corrugated pipe can be used to advantage where the earth cover over the top of the pipe is small. In this case, headwalls are advisable to prevent wagon wheels from crumpling the ends. At ditch crossings, around intersections, at places where water is liable to freeze in the pipe, and for temporary purposes during the construction of large waterways, this material will be found very convenient and satisfactory. Half-round sec-

tions may be used where a hard foundation, such as rock or shale, may be secured. It is important that the thickness of the metal used and the size and number of rivets should be in proportion to the diameter of the pipe.

217. Stone Culverts. — Where there is native stone of any durability and regularity of shape it may often be convenient and economical to build small culverts of roughly dressed stone, laid in cement mortar or laid "dry." The use of mortar saves in labor and the culvert is much more satisfactory.

"Rubble," or undressed stone work, requires careful laying especially if "dry." Large flat stones should be used in the bottom and each stone carefully embedded as the wall is built up, using as few spalls, or small chinking-stones, as possible. Long header-stones should be used as ties at least every two feet of height and three of length.

There is a tendency to use too little mortar in laying rubble. A thick coat of mortar should be spread and the stone firmly embedded in it. The mortar should consist of 1 part Portland cement to 2 or 3 parts clean, coarse sand. The method of using a thin mortar grout poured into the interior of the wall should not be permitted. For spans up to 4 feet, flat cover stones 12 inches or more thick may be used for the top. If there is danger of erosion in the bottom of the culvert it should be paved as already suggested.

Rubble masonry laid in 1 to 3 cement mortar will cost from \$5 to \$6 per cu. yd. "Dry" rubble will cost from \$3.50 to \$4 per cu. yd. These prices will of course vary with the character and abundance of the rubble stone, and of labor sufficiently skilled to do the work. Stone arches, too, have been common since the time of the Pharaohs, — some have pretty nearly lasted since then. The phenomenal development in the use of cement concrete during the past quarter-century should not blind our eyes to the excellencies of the older material. The data in the arch-sheet shown in § 167 is very practical and should be useful to road-builders who have a good local stone to draw upon.

CHAPTER IX

BRIDGES

218. General Considerations. — To the layman there is, perhaps, little distinction between bridges save as to length. They are, however, of numerous types, representing all degrees of cost, durability, and general fitness to special local conditions. In failing to recognize these truths, great amounts of public money have been wasted. This, in turn, is because a long-continued study of such problems alone enables a wise and economical selection of size and type of structure to be made.

Thus, the first steps should be to learn fully the history and range of conditions to be met on the particular stream. In general, this truth seems sufficiently obvious, but if the structure is to be of concrete it is even more desirable to learn them, since if incorrectly located, or otherwise a misfit, corrections can only be made at great cost, and will probably involve the complete destruction of what has been done.

It will be observed that streams have a certain cycle of existence whereof the bridge-builder must needs take notice. For example, the stream may be actively cutting its channel, a characteristic of relatively young streams, and this will continue until it reaches a certain grade, or base level. During this stage the stream generally has a shallow channel, with little head-room, and calls for flat slab or beam construction on the smaller streams with perhaps extensive viaducts on the larger ones.

At a later stage of stream development there may be a well-defined flood plain, across which the stream now has a pronounced tendency to "meander" and frequently change its channel, tho the channel may be markedly deeper. If a hard substratum has been reached, the head-room will be greater, and arches, or even deck trusses may be permissible.

The same considerations also vitally affect the foundation problems, since in the earlier stages of its history the floods will

carry large amounts of silt and sand, certain to produce severe cutting action around the abutments. This is not so likely to occur in older streams which have an established channel. Countless bridge failures have been due to inadequate provision against this erosive action. Hence the necessity for a careful study of the foregoing conditions before determining the type and span of bridge and the style of its foundations.

219. Bridge Engineering. — It makes no difference how good a road is which leads only to an impassable stream. Or perchance, it is just when high water comes in a stream otherwise fordable that the farmer most wants to get to town. In bridges the outstanding fact is that the *best is also cheapest.* There has been and doubtless will be great temptation to practise so-called "economy" when putting-in culverts and minor bridges. Plausible salesmen of bridge companies have often grossly abused the trust reposed in them by confiding officials, — and the public has settled the bills. Most States have been sadly "bitten" on their commonest bridge propositions, and simple and direct bribery is by no means unknown. Unless our commissioners everywhere take to themselves certain bitter lessons sadly learned by countless other officials, much more public money will be wasted in the same way. "The man who is his own lawyer has a fool for his client," the old saw puts it. Paraphrased, "The commissioner without a capable engineer makes a fool of the client," — the client in this case being the public which pays the bills.

220. Essentials to Success. — One State Engineer says: "To enable Boards of County Commissioners to build permanent and economical bridges they should have:

1. The advice of a competent engineer.
2. A profile of the location.
3. Soundings made for the foundation.
4. Reasonable loads determined which the structure is to carry.
5. A good engineer to prepare plans, specifications, and call for bids.
6. Reliable and competent inspectors employed to oversee the work.

"The old practice of having bridge companies make bids on their own plans and specifications has been a most pernicious and unsatisfactory one. Suppose a county board advertises for bids and asks each bridge company to submit its own plans and specifications. There will be as many plans as bidders. One company may have a well designed plan with the greatest amount of steel, a heavy bridge with much shop work. It will be the highest bidder yet have the cheapest bridge, but only an expert bridge engineer could, after considerable calculation, determine that fact. But where all companies are required to bid on one well-designed plan, a plan designed to meet the local situation, a Board is no longer puzzled as to what company's bid to accept.

221. "Counties and townships could well afford, if necessary, to vote bonds for permanent bridges. Future generations would get more benefit than we and they should help pay for them. It would be good business for any county to vote bonds for stone or concrete bridges, provided they employed a competent engineer to prepare the plans and specifications and rigidly inspect the construction work. If such a system were adopted, in 10 years time the bridge and culvert problem would be practically eliminated and at least 50 per cent could be added to the road funds without increasing the taxes."

With respect to most States having State Highway Departments, this bridge and culvert matter need not give any difficulty, as that office frequently issues complete series of plans and specifications for large culverts and small bridges of reinforced concrete, — unquestionably the most permanent and satisfactory material for such purposes.

222. "Tin Bridge" Example. — To show probable results from the old fashioned way we may cite the State Engineer of Kansas, Mr. Gearhart:

"A steel bridge built over the Kansas River in 1900 at a cost of $14,000, was destroyed in 1903, and re-built at a cost of $8,000. It was destroyed again in 1907, and repaired at a cost of $9,000, and was destroyed again in 1910, and rebuilt at a cost of $8,000, making a total cost of $39,000 for this structure in ten years. About four years out of ten, the people had no bridge. For $35,000 a first-class steel bridge could have been built, supported on concrete piers and abutments, and designed heavy enough to carry a concrete floor and a 15-ton traction engine. The present structure has a wood floor and stringers and is a typical 'tin bridge.' At least $20,000 more will be required to make a good bridge of it."

223. Recommended Procedure. — The United States Office of Public Roads says: "A practice which has had an injurious effect, especially in the design of highway bridges, is inviting bids upon the bidder's own plans without having a competent and disinterested engineer to pass upon the design submitted. Under such conditions the wonder is that the bridges are not

Some bridges fail because they are weak.

Others fail because they lack good foundations. This one needed piles under the abutment. It shows also results of deficient waterway.

orse, and the prices charged not more often exorbitant. ublic officials permit the bridge agent to furnish the plans, ıd specifications if there are any, and do the work with a w or no inspections. County boards have no excuse for ındling the public funds in this loose, unbusiness-like manner r they invariably have authority to employ a competent ıgineer." A safe and more systematic course in proposing idge work would be as indicated in § 220.

224. Permanent Bridges. — Permanent bridges include both ose built entirely of masonry and of very heavy steel conructed on masonry piers and abutments.

Reinforced concrete is the material most extensively used ıere the span is not too great. The different types of structres include reinforced concrete slabs, girders, and arches. ıe slabs and girders are especially well adapted to foundations ı ordinary soils, and arches for rock foundations. Arches ay, of course, be built of stone and brick, as well as concrete, ıt these materials are not so extensively used.

Permanent steel bridges should in all ordinary cases be aced on heavy, permanent, masonry foundations. These ould be extended well below the bed of the stream and should supported on piles in ordinary cases, unless they reach to ck. It does not pay to take chances on undermining or ttlement of an expensive masonry abutment for the sake saving a few hundred dollars' expense for piling. High asonry abutments are especially expensive features for peranent bridges. However, a saving of as much as 50 per cent. their cost can often be made by adopting pedestal style structures with an approach span at each end whereby the rth is allowed to assume its natural slope.

225. Temporary Bridges. — These permanent bridges are mewhat expensive to build, and, in view of the large number highway bridges in the ordinary county, it seems that a ınsiderable number of structures must still be reconstructed cheaper material for a number of years. For such cases, a ıod, heavy wooden pile bridge is about the most satisfactory ructure. Such bridges should be made heavy enough to ırry 15- or 20-ton engines.

STEEL BRIDGES

226. "Safety First." — Not only property, but human life is endangered by defective bridges. This alone would justify a much larger charge for proper engineering supervision than would be necessary to secure safe structures. The smallness of the project is no excuse for omitting any part of the inspection or other logical requirements necessary to insure its safety.

227. Failure of Steel Bridges. — Steel is a material which is admirably adapted for highway bridges. Most instances where steel bridges have failed, — and the number of such failures has been great, — have been caused by defective design or construction, and not by faulty material. Not a few failures have also resulted from *lack of* proper *maintenance.* Permitting rust to make inroads into the metal from the lack of paint, or neglecting necessary minor repairs is to be condemned no less severely than the practice of adopting an inferior design or permitting faulty construction at the beginning. The phrase "Tin Bridges" has gained unfortunate prominence thru unscrupulous contractors using structural shapes so thin and light that after the formation of a coat of rust on each side there is scarcely anything left. Needless to say such bridges often become a great menace to public safety soon after their completion.

228. Control by Specifications. — Attention is called to a few precautions needful to secure satisfactory designs. Leading defects common in steel highway bridges will be pointed out and means suggested to avoid them.

The majority of small steel highway bridges are at present designed by the companies who erect them. It is bad practice to invite bids for designing and constructing a proposed bridge, without first having prescribed a definite set of specifications to which the design must conform. Otherwise, there will be no standard of excellence to serve as a basis upon which the different proposals may be compared, and irresponsible parties are likely to secure the contract by submitting low bids based upon very light and probably unsafe designs.

The specifications for a proposed bridge should fix the maximum concentrated load, the maximum uniformly distributed load, and the safe working unit strength of the steel in tension, compression and shear, the minimum thickness of metal, the character of the connections and other details, and should specify definitely concerning the quality of the materials and workmanship. They should always be accompanied by a drawing, prepared for the purchasers by a competent engineer, showing plans for the masonry abutments and piers, and giving the general dimensions of the bridge.

229. Drawings. — All proposals to furnish and erect bridges should be accompanied by the contractor's general drawings showing the size and shape of the different members. Before a contract is awarded the designs should always be checked by the purchasers' engineer. The contractor should likewise furnish complete working drawings of the bridge, and these should also be carefully checked by the engineer before any material is ordered or shop work started. As already stated, it would be much better if the plans were prepared by an independent engineer at the beginning.

230. Shop Inspection. — Upon completion of the shop work before shipment has been made, the purchasers' engineer should visit and carefully inspect each bridge-member at the plant, approving those which comply with the shop drawings, and condemning defective parts. In very few cases have purchasers of small highway bridges taken this precaution, but often it would have been abundantly justified.

Field Inspection. — Every bridge should of course be carefully inspected after erection and before it is finally accepted; but it works a much greater hardship on the contractor to condemn any part of a bridge after it is erected than it would to condemn the same part in the shop. There is a much greater temptation for the engineer to overlook slight defects. A large percentage of the bridges which are not inspected in the shop are defective.

Not infrequently, bridges are designed, fabricated, erected and accepted by the purchasers without either the plans or the bridge being inspected by any representative of the purchasers who is competent to judge the class of work. This practice usually results in generally weak details, poorly driven rivets, improperly packed pins, insufficient anchorage,

failure to properly provide for expansion and contraction, poor painting, and numerous other defects.

231. Maintenance Needed. — It has been well said that in road-building the bridge problem is more important than the road, for if the roads are to be used at all the bridges must be kept up. It costs just as much to construct and maintain a bridge in a lane as on a heavily traveled highway. They rot, and rust, and wash out just as fast in one place as in another. It is not the travel but the elements that chiefly destroy the bridges.

232. Money Wasted. — In most of our Western States it has long been true that about one-half of the large sums spent for bridges and culverts by the counties and townships was wasted and squandered due to ignorance, the use of poor materials, faulty design, no specifications, lack of skilled inspection and supervision, bridge pooling, illegal letting of bridge contracts and selling at exorbitant prices.

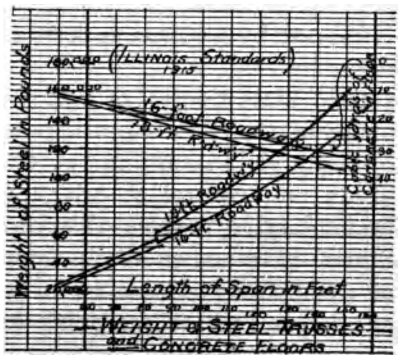
BAD PIERS. As a concrete illustration of waste, Mr. Gearhart of Kansas says: "Overturning of steel tubular piers has caused numberless bridge failures. Almost without exception on rivers having ice floes the tubular-pier foundation construction has been a curse to the State. It is a little cheaper in first cost than stone or concrete, but if it had not been urged by the bridge agents funds would have been provided *somehow* to put in stone or concrete piers and abutments. The necessary funds to *re*build them are usually available *after* they have failed. If stone or concrete foundations had been used at first, the original steel superstructure would generally have been in continuous use until the present time. There are very few of these bridges on tubular piers on the rivers referred to that are ten years old on which there has not been spent more than enough to have had them right at first."

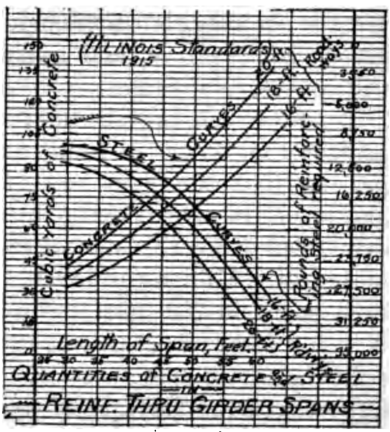
BAD FOUNDATION. "I inspected some concrete foundation-work recently and found the foreman placing large soft dry stones in the wall close together. The dry stones absorbed the water in the concrete and it would never set. This structure when finished makes a shell filled with dry rock. There were no specifications for this work and no inspector on the job. Concrete was worth about $10 to the contractor and stone about $2 per cubic yard; hence the reason for the excess of worthless stone."

233. Estimating Curves for Bridges. — Engineers and contractors must often quickly prepare estimates of quantities of the material in various types of highway bridges. The preparation of standard bridge plans by various highway Departments has made it possible to construct curves which greatly

facilitate the estimating work. Especially do they assist the field engineer in making reliable estimates and permit any official to make at least a rough check on quantities and costs, to the end that blunders or graft may be more certainly detected.

The preparation of estimates is of equal importance to the field and to the office man, but the former most needs convenient and reasonably accurate data upon which to base them. The cost of labor and materials must be determined for each job, and it cannot be estimated by any set rule. But the quantities of materials required for any job can be estimated very closely by means of tables or curves when the plans are standardized. The curves given herewith deal with quantities only, and are intended primarily for use in the field, and for preliminary plans. (See diagrams.)





234. Estimating Steel Trusses. — These steel trusses are ordinary Pratt type with parallel chords, riveted connections, and have a 4-in. concrete floor, with a wearing surface, or pavement, assumed to weigh not less than 50 lbs. to the square foot, no allowance made for impact. Designs carry 15-ton traction engine in addition to the dead load. Trusses designed for a uniform live load of 100 lbs. per square foot of roadway for spans of from 50 to 150 ft., and for a uniform load of 85 lbs. per

square foot for spans of over 150 ft. Tension members are designed for 16,000 lbs. and compression members not to exceed 14,000 lbs. per square inch. Pony trusses are used for spans from 50 to 85 ft. and thru trusses from 90 to 160 ft. (See diagram.)

Reinforced Concrete Thru Girders. — Reinforced concrete thru girders are used for spans from 30 to 60 ft. The design is to carry a uniform load of 125 lbs. per square foot or an engine load of 24 tons, and wearing surface weighing 50 lbs. per square foot. Free expansion and contraction is provided for by castiron rockers under each girder at one end of the span.

235. State Control of Bridge Work. — There is probably no phase of the State's participation in road work which would so easily yield such important results as the systematic supervision and control of bridge work. Most Commissions are taking active steps in this direction. The majority of the States have an enormous number of inferior bridges, both of wood and steel, on highways where more or less important improvements are going forward. It is natural that the expenditure necessary to replace these bridges adequately should be postponed until new surfacing, which makes a greater showing, is completed. But this makes a very dangerous combination, and numerous accidents have been and will continue to result.

The State can, and should, prescribe the kind and strength of bridges that must be built, and insist upon State authority passing upon the plans and construction of these bridges, regardless of the origin of the funds which pay for them. This is demanded from the standpoint of public safety alone. Nor is this all. Millions of dollars of bridge money has in the past been spent in the most unbusiness-like way, being in fact a favorite form of graft for unscrupulous road officials and politicians. In some cases the guilt has been so flagrant that important sums have been recovered for work actually never received, when once honest and enlightened public officials, backed up by an adequate public opinion, have taken matters in hand.

236. Bridges and Grade Crossings. — With the growth in population and traffic of rural communities, bringing increased railroad facilities also, the number of crossings between highways and railroads will increase, as will also the road traffic, thus increasing the dangers inherent in these intersections.

Iowa, for example, finds that she has nearly 9,000 of these crossings outside of her towns, and her county supervisors class 900 of them as dangerous. Her State Commission, however, is making a notable beginning in their elimination. Since the investigations of the first thirty crossings taken up showed an average cost of about $4,500 to make each improvement, the immensity of the work from a financial standpoint becomes obvious. It is plain, therefore, that in every State a systematic beginning and continuous activity in this direction must be carried forward, else the death-toll will be steady and of enormous magnitude.

237. — Since the typical grade-crossing elimination calls for a highway bridge over the railroad, or a railroad bridge over the highway, a brief consideration of the matter will be in order here. First, it should be noted that not all dangerous crossings call particularly for bridges, or will be likely to get them for a long time to come. At these the danger is usually due to an obstructed view, whereby the unfamiliar traveler, — the commonest kind in these days of the auto, — drives into a trap. The obstruction may be due to trees, buildings, growing crops, weeds, — in either of which cases the remedy is sufficiently obvious.

Where either the highway or the railroad is in a cut, with either a steep incline up or down to reach the track level, the dangers are vastly increased. Yet many of these locations in cuts can be made infinitely safer by simple grading operations, taking off the top of a bank, for example, so that the road-user can get a fair view of the track in both directions before reaching it.

But the mere use of a bridge of some sort does not always solve the difficulties. Sharp turns and a steep grade in negotiating either the overhead or undergrade crossing are a serious menace to rapidly moving autos, substituting the less

terrifying but still real danger of colliding with other travelers for that of being struck by a train. It follows that no two crossings will present precisely the same elements for solution, and each must be treated individually and with intelligent care. Intervisibility of travelers from each direction is found to be a prime essential.

Even with a bridge of some sort there are still other dangers as to the stability of the structures involved. There is the danger of collapse, fires, and floods, according to location and type of construction, which may precipitate a train onto a road below, or where the highway passes over a railroad on a flimsy structure which is unfortunately common, heavy loads or traction engines may go thru to the track below, — with consequences which need not be enlarged upon.

238. Procedure. — The State law should provide a plan whereby grade-crossings may be eliminated, stating a scheme for arriving at an apportionment of the cost according to the benefits. Some States tend to put the cost wholly upon the railroads, which is manifestly unfair, especially as to roads opened subsequent to the railroad's occupation, and which have relatively light travel. Others desire that the cost be borne for the major part by the immediate political unit, such as township or county. Still another plan introduces the interests of the State in the safety of its citizens in general. It seems, therefore, just and fair that there should be participation in the expense by all three, as perhaps, the State to pay 20 per cent, county and township 30 per cent, and railroad 50 per cent, with modifications of these ratios lying in the power of the State Railroad and Highway Commissions to more justly adapt them to given cases.

Procedure could start by a complaint against a crossing made by a local official filed with the State Highway Commission. One of its engineers, with special experience, could then investigate the crossing, devise a plan for its improvement, gather all necessary data, and estimate the cost. He would then recommend the apportionment of cost to be made, submitting the same to the various Boards involved, and to representatives of the railroad, until an agreement could be arrived at by

Too much water *on* the road! Also note that everybody's business is nobody's business.

Too much water *under* the road.

A common type of trap-crossing.

A granary hid the view at this crossing. Death lurked here,— and caught two.

conference. Special legal procedure might be arranged in case agreement was not possible.

This discussion is intended only to relate to crossings on country roads. Street crossing eliminations in cities and large towns form a much more complex and difficult group of problems, not properly treated here.

CHAPTER X

ROAD FINANCE

The essential idea of this chapter is that roads cost a lot of money, and that its collection must come from a great number of people, else it becomes unduly burdensome. Further, the cost should be borne by those most benefitted.

Bond issues, next to taxes, furnish a leading source of funds. Tho easily raised, it is still easier to spend bond proceeds unwisely, and with disappointing results. Numerous important incidental obligations attendant upon bonding operations are here treated at length. The practical basis for road construction by improvement districts is fully explained, with examples, followed by a brief consideration of automobile licenses as a source of road revenues.

The chapter closes with a few remarks upon Town Highway Accounts.

239. Road Finance. — Four main plans for raising money are common. The first and oldest is by direct taxation. Little comment upon this plan is needed here, save to emphasize the necessity of well-considered and intelligent expenditure of the proceeds, and providing an adequate maintenance scheme. The second plan uses bond issues; the third relates itself to automobiles in some way; the fourth is by special assessments. Each of these will be considered.

240. Road Bonds. — In most cases the annual proceeds from taxes do not yield enuf to make extensive improvements. Even if administered to the best advantage, it takes a long term of years to complete any comprehensive plan. A bond issue is therefore sought to secure the immediate advantages which good roads bring. In theory the added usefulness of the road is worth the annual added expense of interest and sinking-fund on the bonds, while the resulting appreciation of property values is clear and immediate gain. This is sound reasoning as far as it goes.

Further, the annual tax funds scattered over the county are insufficient to make any important improvements. Yet if

concentrated upon a single road general funds would thus be contributed by those who had no direct benefit from them, — a plan unworkable and inequitable.

But if financed by bonds a large amount is available at once, and extensive projects of wide benefit can be carried out. Also large contracts can usually be made at a less cost per mile than if the work is done piece-meal.

Still another important reason for bond issues is that if the work will benefit future generations in increased facilities for transportation and enchanced land values, then it is fair that they should contribute to the cost. And also, the costs should be spread over a term proportionate to the life of the improvement during which those paying for it will be profiting by the results of the work, and will be better able to contribute towards its cost.

While the general arguments can be thus easily stated, justice to all the interests involved and adherence to the principles of sound finance (without which no policy can be permanently successful), requires more study of certain immensely important phases than have commonly been given them.

241. Incidental Obligations. — A discussion of bonds as a means of road finance should not fail to emphasize the importance of careful preliminary investigations and plans of construction, to insure that the proceeds are not largely wasted thru some of the channels already indicated.

It also requires a careful determination of the additional taxation required for bond interest, and for creating a sinking-fund to extinguish the bonds at maturity. Last, and most vital of all, it must be planned how the roads are to be consistently and intelligently maintained when built. Many interested persons do not fully realize the necessity for providing in advance for adequate maintenance, yet without it the bond proceeds are largely thrown away, as will be shown later.

That this topic is worthy of careful consideration is shown by the fact that the Southern States alone issued road bonds in excess of twenty-five million dollars in 1914.

242. Scientific Control Demanded. — The demand for proper safeguarding of the expenditure of these enormous sums is

steadily growing. Virginia supervises road-bond work thru her State Highway Commission. Mississippi requires that proceeds of county road bonds shall be expended under skilled engineering supervision only. Tennessee requires that 2 per cent of the original amount of the bond issues shall be annually raised by taxation for maintaining the roads constructed by such bonds. In all States which have advanced far enuf to permit it, the public has become convinced that such scientific supervision is not only an excellent safeguard against waste and graft, but is also a paying investment.

243. Bonds Outliving Construction.—*Common Errors.* Competent engineers place the average life of macadam roads at less than ten years. It is unwise, therefore, to issue for them bonds for forty, thirty, or even twenty years. It is unjust to the coming generation unless the road has a corresponding period of usefulness. That every bond issue should also be based upon a plan absolutely requiring thoro and continuous maintenance is a proposition which admits of no argument.

Let us compare road bonds with the railroad bond, a security with which the general public is fairly familiar, but let us not permit the practice in one field to lead us to unsound habits of thought in the other unless the conditions warrant it.

244. Railway and Highway Bonds Compared. — For construction purposes a railroad commonly borrows money on bonds (which are simply formal promises to pay, substantially like promissory notes), basing them upon the market value of its property as security. It usually does not attempt to set aside from its earnings an amount which would permit it to take up and discharge these bonds in full at their maturity. Instead, it pays bond-interest, maintenance and operating expenses, and usually steadily makes betterments also, — all of which come out of its gross earnings.

Then, after setting aside a reasonable working surplus for contingencies, it distributes the balance of its earnings to its stock-holders. When the maturity-dates of its bonds approach, it commonly sells new bonds to an equal amount and with the proceeds takes up or retires the old ones. Or, it *often* merely exchanges new bonds for the matured ones, per-

haps without any interchange of cash at all, especially if the investor (i. e. the bond-holder), is satisfied to leave his money in the enterprise. Viewed from the ordinary person's standpoint of paying off a debt, it will be correct to say that railroad bonds were never *meant* to be paid off in cash, in this sense. By this is meant the way in which a business man would borrow money to set himself up in business.

A vital factor, also, not to be overlooked, is that by constant maintenance and betterments made from traffic-earnings, the railroad is offering still better security to the new bond-holder than even his predecessor had. This also shows that if the financial plan has been honestly administered, and the money has been actually and wisely invested in the plant, then there is no reason why in fact the bonds should ever be "paid off" in the common understanding, as of discharging a debt. Let us now see how these considerations apply to bonds for public roads and bridges.

245. — The first and most important difference is that since roads and bridges are public enterprises they have no cash earnings with which to pay interest, maintenance, or betterments. The most obvious lesson, therefore, is that unless a substantial portion of the original amount is set aside for maintenance, or unless there is a steady and consistent program of taxation for that purpose, the road will, in the case of long-term bonds, be worn out perhaps three or more times before it is wholly paid for.

This is so whether the bonds are serial, some of which mature annually, or term-bonds all maturing at once, against which time a sinking-fund has been accumulated. In either case, if the work is worn out before being paid for, those who come last before the bonds mature are paying for something which they never had.

246. — For example, suppose the road lasts seven years without maintenance, but that the bonds which pay for it run twenty. Thus two entire replacements have been added to the original construction, and at the end of the twenty years the cost of three pavements would be represented by the one then in use, — and *it* would be six-sevenths worn out. This

discussion presupposes, of course, that building the second and third pavements costs amounts equal to the first.

Let us take $1,000 as an illustration which, in 1915, is put into a thousand dollar's worth of work. In 1922 the work is gone, and it takes another $1,000 to replace it. Then we may say the same again in 1929, making $3,000 spent, but this will then last one year after the first bonds mature, in 1936. For the 20-year period, therefore, this improvement has cost an average of $150 annually, or since we must replace again so soon, it would be more nearly correct to say $3,900/20 = $195.

If now we assume that 12 to 15 per cent of the first cost is a fair charge for maintenance (which it often is), and assume that constant maintenance will keep the work good for the whole twenty-year period, while the first cost is itself divided over the same period, let us see what appears. To $150 (which is the annual maintenance charge) must be added bond-interest and sinking-fund, say another 10 per cent, or $100, making $250 as the total annual cost of enjoying this improvement.

This seems to show that it *is* cheaper to let it wear out after all, with no maintenance at all. But look again. Under this plan we still have the pavement, whose value is say, 80 per cent of new, which spread over the 20 years would reduce the annual cost by $40, or to $210, and with a continued similar charge can keep it indefinitely, or can start afresh, since the original bond obligations are now cancelled. But that is not all.

Many attractive business projects have come to grief simply thru ignoring the operation of that potential business force called "interest." Let us see if it is not so here. Under the no-maintenance plan, suppose also that the bonds bear 6 per cent interest, and that the twenty-year sinking-fund plan means an average of about 4 per cent annually, or a little more for it. Then the total of these two is $100 for each of the first seven years. For the second seven, beginning in 1922, a similar charge must be added, so that for this period it is $200 annually. Then from the fourteenth to the twentieth years, another similar charge must again be added, so here the total annual cost is $300 per year, — a total of $3900 and an average of $195. Where then is the saving? Note here, as vastly important, that the work is practically worn out when these burdensome payments come to an end. But even *that* is not the worst of the whole matter.

We are now considering a no-maintenance plan, where the work lasts seven years, and then is wholly worn out. For how long will the work remain substantially new, so that its condition is really good? Two years is probably a high figure. For the next two it will doubtless pass rapidly from bad to worse, and for the last three it will doubtless be bad indeed, and must be wholly replaced. For more than two-thirds of the time, therefore, the public has had a bad road, or worse, while *all of the time* it has been paying enuf to have had a first-class one. Plainly this is not what the American public wants, and is willing to pay for. It thus appears that "A stitch in time saves nine" in road-making and road-finance just as truly as anywhere else.

247.—But the foregoing discussion does not truly represent actual road-building conditions. It supposes that subsequent bond issues can be easily floated for the re-construction of worn-*out roads* not yet paid for. Could a business man whose se-

curity was formerly good, continue to borrow money on it when it became worn out, impoverished, or worthless? Assuredly not. Neither as a policy, can political units continue to do the same when the investing public attains a discriminating knowledge in such matters. The conclusions therefore, cannot be avoided. With proper maintenance, the life of the road is commensurate to a proper bond period and the effect is that everyone is paying a fair price for what he is getting while he is getting it. But without such maintenance, the users must pay an accumulating burden of debt up to the maturity of the first bonds, and thenceforth vastly higher than in the continuous maintenance plan, supposing the subsequent bond issues can always be safely floated. But if they cannot, then for something like three-fourths of the entire period the road users are paying for something which they are not getting at all, — a good and usable road.

248. Deferred Payments: When? — The foregoing discussion seeks to show that there has been a deal of loose thinking on road-bond matters. But there is a proper place for long term bonds in road work which it is hoped the public will soon come to appreciate. Let us look into this more closely.

The elements which go to make up the cost of important road improvements are substantially these: Surveys, purchase of right of way if necessary, building of culverts, bridges, and other drainage structures, earth-work to reduce grades (meaning the excavation of hills and filling of valleys), compacting and solidifying the grade, and finally the construction of the improved road surfacing, whatever it may be. Practically all of these items, save the last, fall into the same group. Once properly done these parts of the improvement are permanent, or are at least good for decades, possibly for centuries. It is the road surfacing alone which receives the wear and deterioration due to traffic, and must be sooner or later renewed, and around this the previous discussion has centered.

It is plain therefore, that long term bonds are appropriate to raise money for all the purposes in the first group, but are not fitting for short-lived surfacing. This distinction has not commonly been recognized. It illustrates the incontrovertible

principle that roads cannot be built successfully by wholesale general plans, any more than a physician can cure patients, or a lawyer handle clients on a wholesale and invariable scheme of treatment. They are individual cases, and must be handled as such. The bane of road-building in America today is and has been the effort to apply unthinkingly and unintelligently methods which because they have been successful in one place, are sought to be applied under conditions where they do not fit at all.

It appears, too, that there is no fixed rule of proportion between groups one and two, discussed above. Consider each case by itself. The surfacing costs may vary from substantially the whole expenditure, to say less than forty per cent of it. The life of the bonds should be arranged to match the actual conditions, as explained at length. To do otherwise, places a severe economic burden where it does not belong.

249. Serial *versus* Straight-Term Bonds. — Straight-term bonds, meaning to make a whole series, or issue, payable twenty years from date, for example, usually include a plan for a "sinking-fund" except in the case of a railroad bond, as already explained. The "sinking-fund" is a financial device resting upon the fact that compound interest, growing thru a long term of years, mounts up rapidly at the end, and by reason of the added benefit of compounding the interest, the annual payments called for are less than would be the case were the interest not so compounded.

For example, to yield $1.00 at the end of 20 years, with compound interest at 5 per cent, an annual saving of 3 cents will suffice, tho the amount so actually saved by the investor has been but 60 cents. On this basis, a $50,000 bond issue would require that $1,500 be set aside for the sinking fund. If the bonds carried say 7 per cent interest, an additional amount of $3,500 would have to be provided also, making $5,000 the cost to the tax-payers annually on account of these bonds according to the financial bargain contained in them. The expense involved in maintenance is not now under discussion.

250. Sinking-Funds. — The sinking fund has been a favorite financial device for many years. Apparently it has great merit. What, if any, are its shortcomings? The first requisite is an absolutely safe depositary. Failing this, the scheme of course breaks down, and many such a sinking-fund holder has in fact absconded with the money, or lost it thru his own bad investments. It is of course a general banking principle that the banker pays interest for money in order that he may invest it for a greater return for himself. As an investor he may be either dishonest,

or incompetent, or, tho blameless, be the victim of circumstances for which he is in no wise responsible. Necessarily, therefore, the sinking-fund in his hands shares in all these risks to a greater or less extent. In private banking there is probably no infallible safeguard that can be thrown around him or the sinking fund.

Another element of uncertainty lies in changing interest rates. Economic crises of world-wide significance may affect them suddenly, or they may be subject to slow but steady changes, due to more local conditions. If the banker bids high for sinking-funds because the current rates are then high, they are most certain to come down before the long term has ended. Hence the temptation or necessity for him to seek to make large earnings on speculative enterprises, to the great risk of the sinking fund, as before. If thus lost, these funds must be simply paid over again by the long-suffering public. If, on the other hand, the banker bids low, because the current rates are low, they will probably rise before the bonds mature, and the public must in this case pay a greater annual amount because the money will not compound so rapidly at the lower interest rate. But this, however, does not make the depositary any safer than in the first case.

251. Serial Bonds.—Most of the risks and uncertainties of the sinking-fund plan can be easily avoided by what are called "serial" bonds. This means that if $50,000 is to be raised, and the repayment is to be complete at the end of 20 years, then whatever their denomination, as $100, $500, or $1,000, a total of $2,500 will mature on each of the twenty years. The interest on that amount and the successive similar sums of course ceases when the individual bond is paid off.

In the case similar to that above, the amount to be paid out at the end of the first year would be $2,500 plus 7 per cent (if that is the rate) on the $50,000, or $3,500, making a total of $6,000, against $5,000 on the other plan. But this interest charge will diminish by $175 per year until it reaches the $2,500 called for by the bonds in the last year, whereas in the first plan the $5,000 is a continuing charge for each of the 20 years. Making this computation of interest under the serial plan, it shows a total of $36,750 for interest alone, or an annual average of $1837.50. Adding the $2,500 for each of the bonds gives $4,337.50 as the annual total for the serial plan. This is an annual average saving of $662.50 over the straight-term plan, or $13,250 during the 20 years. This, it will be seen, is a total saving of 26½ per cent of the original issue, in favor of the serial and against the sinking-fund plan. Besides this, all the worry and risk incident to custody of the sinking-fund is done away with. No one can abscond with anything worth while. And if the burden is a trifle higher at first, this is no more than fair, since then the road surface is new and in the best possible condition.

252. Dividing the Expense. — Every citizen desires the maximum benefits from road work at the least expense. He should also pay fairly and proportionately for benefits received. This involves questions of State Aid, State, County, and Road District Bonds. While the principle is easily stated, to work it

out justly in every case is often difficult. The foregoing analysis of bond obligations applies whether issued by State, County or District. It dealt with the incidents of raising money by that method. We are now to consider from what sources money ought to come.

Observation shows that roads vary in importance, and that fifteen per cent of them carry probably ninety per cent of the traffic. In homely phrase, "They *go* somewhere and *get* somewhere." The roads carrying the densest traffic should to a considerable extent be assisted by the State, because the people of a wide area use them, and the better they are the more of an asset they become to the State as a whole. There is no good argument why the local community should entirely support these very widely used roads.

The next roads in importance are those for which the county should be chiefly responsible, while the least used should be maintained locally. Any system which does not recognize clearly these general divisions is in serious economic error. Most States do recognize them to a greater or less degree.

The fallacy is common that State Aid relieves from local taxation. In general this is not so since roads require real money whether called county, township, or State taxes. The State tax does, however, distribute the tax more broadly and should be applied only to undertakings where it is right that a broad general contribution should be made, and where the benefits are to a considerable extent non-local. Among the different States there are numberless variations of plans whereby the expense of road work is apportioned. No attempt will be made to classify them here.

253. Automobile Funds. — This is an interesting topic, with different aspects according to the viewpoint. Special taxation or licensing of autos has become firmly establisht, the income from this source in some States amounting to nearly a million dollars yearly. From the standpoint of unlimited general use of public roads there seems to be no reason why automobile users should be specially taxed, any more than the owner of a horse and buggy, and especially the user of narrow-*tired* vehicles. On the other hand, the wide use of these

machines has without doubt been vastly more destructive to road surfaces than the normal amount of animal-driven traffic would have been in the same period. Hence it is only fair that a special burden should be put upon those who own and benefit by them. This money should also be expended in some way of direct benefit to the roads. It is further true that autoists have been steadfast "boosters" for all sorts of road betterments. In their enthusiasm they have voluntarily shouldered tax burdens more than they will doubtless be willing to continue to do indefinitely, especially as the use of machines is becoming so general. They are becoming units of far-reaching importance in the transportation system of the country.

A heavy auto-tax being now an establisht institution, what should be done with the proceeds? People whose minds run to extreme localization in everything say this license should be collected and expended by the smallest political unit, as township, village, or city. The next broader-minded class says it should be collected and administered wholly in behalf of the county. Reflection shows that a still broader view is more rational. The fact that autos are in their very nature mostly used in inter-county and inter-state travel, shows that the county is too small a unit to deal with in this matter. If so handled the smaller and poorer county with small road revenues finds its roads habitually worn out by autos belonging to its larger and richer neighbors, with no prospect of ever righting the growing inequality. This view rests on the assumption that auto funds are large enuf to play an important part in general road revenues, as is the case in most States today.

254. — Probably the most common, and best practice, is for the State to license autoists. The fee runs from a merely nominal sum to $30 or $40 for the most powerful machines, in some States. As a State revenue, then the question remains, how can it best be expended? In many States where the State Aid plan is in force in some form, the auto funds are incorporated into it some way. Those who habitually plead for *more* roads, neglecting that vital element, maintenance, would turn the auto money into new construction, usually arguing, it is

true, for "permanent roads," but entirely ignoring, or ignorant of, the fact that *there is no such thing as a permanent road.*

Others, with broader view and keener vision, would divert the auto funds wholly or substantially to maintenance. If administered by the State upon wisely chosen "State Roads," this is probably the most logical and best solution of the problem. This plan, however, contemplates the inclusion of at least the more important "county" roads, or what might fairly be called such, within the class of "State" roads.

The State Highway Commission, too, could fairly be supported and made effective thru the auto funds. Iowa, for example, diverts a fixed percentage of the license money to the exclusive administrative purposes of its Commission, this fund at the present time being sufficient to maintain an efficient personnel of from forty to fifty persons.

255. Conclusions. — It is perhaps not important, and is probably impossible to so perfectly adjust the apportionment of tax burdens that all share in absolute proportion to the benefits received. It *is* desirable that this result be obtained as far as practicable. The extent to which it is accomplished must always depend upon the statesmanship and clear-sightedness of those who frame our laws. At present every conceivable variation and combination of the elements enumerated seems to have been made in some State or other, and it would be hopeless to attempt a classification of them here. As a general truth, the use of ordinary taxes for road construction, and so-called permanent improvements, with auto funds practically all going to maintenance, and administered with the State as the unit, is the most logical plan.

256. State Aid and Local Assessments. — The principle of State Aid as already suggested, recognizes the scope of benefits by road improvements on important traffic arteries as extending beyond county limits. Many States have set an arbitrary proportion which the State will contribute when the county shall have interested itself sufficiently to raise its share for new construction. In many of these cases, maintenance has not been duly considered, and the ultimate burden on the local communities may be greater than they would otherwise have undertaken. The proportion of State Aid, where given, is

therefore a vital matter in the long run, and should be speedily adjusted to give the greatest benefits at the least expense to all interested. In the same State it may be expected to vary with the class of improvements, with the growth of traffic, and with the property development of the community. The laws should be so framed as to permit its adjustment.

The phrase "*local assessments,*" however, is generally used in a more narrow sense. The root-principle is that good roads enchance the values of adjacent property. The governing idea is seen to be that the public should contribute generally and without distinction to the construction and maintenance of a road system, all of which conforms substantially to the same general standard. As soon as a road markedly better than the average is built at any place, then that immediate locality receives a special benefit in which localities lying at some distance share practically not at all. It follows that the locality specially benefited should make some special contribution to the cost in proportion to its benefits. It also follows that the greater the degree of improvement, and the more expensive it is, the greater contribution, or local assessment should be made for it.

The practice of American cities with respect to paving taxes illustrates this principle, tho the practice varies from requiring abutting property-holders to pay the total cost of construction, to where the city contributes perhaps half, and of course subsequently maintains it. There is every reason why this principle should be put into effect with expensive country road improvements, such as paving with brick or concrete, macadamizing, graveling, oiling, etc., the abutting property owners' share decreasing according to the scale just mentioned.

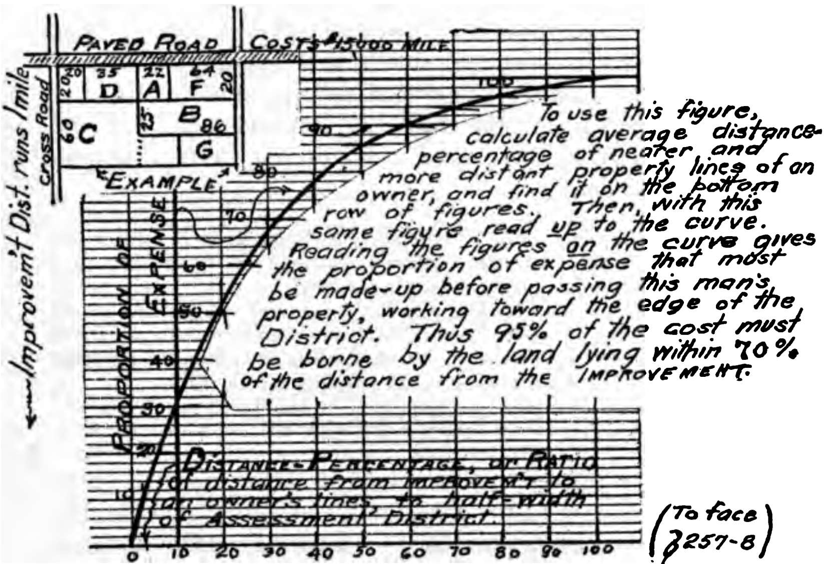
To hold otherwise is to declare that the theory of the "unearned increment" is untrue, and that it *is* right for the many to pay taxes to unjustly enrich the few.

But assessments should not be placed solely against property immediately adjacent to the road improved. It can be readily shown that the benefits extend to a considerable distance in either direction away from it. To extend the assessment two or three miles from the road on both sides would generally be fair, the distant lands paying a less amount, and would prevent an undue burden from falling on any one. Many States are moving in this direction. Oregon is one of the first to attempt to put this method of apportioning assessments

upon anything like a systematic basis. A more detailed explanation with an illustration of an Improvement district follows.

Short-Lived Organization. — A current tendency in these local assessment and improvement district plans, but which must ultimately be corrected, is to allow the necessary organization to lapse as soon as the original construction is completed. No provision is commonly made for maintenance, nor no continuing plan contemplated for future work, nor information collected upon which to prove or disprove the wisdom of making a similar choice again. These are economic and administrative defects which must be remedied.

257. Improvement Districts. — In cases where exceptionally costly construction is desired, say concrete or brick paving,



IMPROVEMENT DISTRICT ASSESSMENT DIAGRAM

and for which there are not nearly sufficient funds derived from ordinary taxation, or where the direct benefits will be *more* local than general, and especially where the improvement

is of such a type as to very markedly enhance the values of adjacent property, voluntary *improvement districts*, independent of political or municipal lines, are sometimes formed. This is a wise and equitable plan, and is also especially appropriate where for one reason or another bond issues are not available as a means of finance. As just stated, the basic principle is that adjacent property will be greatly enhanced in valuation, and the extent of its enhancement will depend upon the distance away from the improvement. It is further true that this increase is not in a simple ratio to the distance, hence the difficulties of apportioning the cost equitably has often given rise to much confusion, and considerable contention. Since the apportionment is difficult to make at best, there would always be many who felt they were being unfairly treated. It is not so important exactly *what* the rule of apportionment is as it is important that it operates to treat every land-owner upon exactly the same basis. If it does not, disaster is certain to befall the project.

To assist in such cases there is presented herewith a diagram which represents good practice in this direction. A glance at it shows that 50 per cent of the cost should be borne in the first fifth, or 20 per cent of the distance from the improved road; 90 per cent of the cost within 60 per cent of the distance out, etc. Being based upon percentages, the width of the District will make no difference in its application, so it may be used equally well for city lots or for farms of varying sizes in a District, say two miles wide. To make it plainer, there is a diagram showing illustrative cases, in the upper left-hand corner of the figure, and three cases will be worked out, as examples.

PROBLEMS

258. Problem 1. — It is required to find the total cost to the owner of lot "D" (see diagram) for a proposed brick-paved road abutting his land, costing $15,000 per mile. The district is to be two miles wide, hence a mile on each side bears the cost of half the pavement, or $7,500. Figures on the sketch give rods; 320 rods make a mile.

First, find the "distance-percentage" or ratio of the middle-distance of a man's land to the total half-width of the district. D's depth is 20 rods, hence his average depth, or "middle-distance" is 10 rods, which is one-thirty-second of a mile. But 1/32 equals 3.1 per cent which, being sought on the bottom row of figures of the diagram, and then being read upward to the curve, we find our (imaginary) line to cut the curve at a distance between 10 and 20 which we may designate as 12 per cent. This means that D, tho his land extends back but about three per cent of the width of the district, must still pay 12 per cent of the cost of all that pavement which lies on his frontage, — wholly because his land, lying *on* the improve-

ment, will be most benefitted by it. Of course the balance of the cost for the same frontage will be shared-in by those behind him, in varying proportions. To find his expense in money will now be easy.

A cost of $15,000 per mile is $47 per rod, or $23.50 for the half-width. D's share of 12 per cent is, therefore, $2.82 per rod of frontage; since he has 35 rods of frontage, he will have to pay $98.70 as his share, or less than 20 cents per front foot.

Problem 2. — How much will "B" have to pay with about three times as much area, and 2½ times as much length (parallel to the pavement) but lying back a short distance?

The average "distance-percentage," or "middle-distance" from the pavement is seen to be 20 plus 25 divided by 2, plus 20 divided by 2, equals 32½ rods. This is substantially 10 per cent of the mile (320 rods), and we find that the 10 per cent line cuts the curve at 30, meaning that 30 per cent of the cost for any rod of frontage must be taken up before we pass B's south line to the next owner. Since, however, we have just found that the first 20 rods of depth took up 12 per cent of the cost, B will therefore only have to pay the balance, or 30 minus 12 equals 18 per cent.

Eighteen per cent of $23.50 is $4.23 per front rod, or distance along the pavement. B's land extends 86 rods in this direction, hence the total assessment on him is $363.78.

Problem 3. — What will C's assessment be, whose piece of land lies with two different depths in respect to the pavement?

We shall proceed exactly as before, after having divided his land into pieces, 60 × 55, and 22 × 35, respectively, and treating each piece separately, adding the two results together for his total assessment.

In this manner, any size or shape of piece, lying anywhere within the boundaries of the Improvement District may be handled, and its share of the cost ascertained. It will be clear, of course, that the share of the more distant owners rapidly decreases, so that those in the outside half pay only a total of ten per cent of the cost, as plainly shown in the diagram.

259. Simplified Town Highway Accounts. — Mr. Buck, of the New York Highway Department, says:

"In conducting the work of any town highway system organized as a branch of the State system, simplicity must be the watchword. The road mileage is large, the amount of money small, and the agencies expending them all should be required to give a close adherence to definite, plain, and simple methods, in accounting as well as elsewhere.

"If the system can be easily followed by local officials in actual charge of work, there are two important results. First, a complete and accurate record of funds expended; second, the lessons of order and system learned are carried, perhaps

unconsciously, to other parts of the work, obtaining a more orderly, systematic and effective management of the whole.

"The New York system of town highway accounts has proven very satisfactory. The funds are derived from two sources. First, a local tax upon the several towns, supplemented by "State Aid" depending upon the assessed valuation per mile of town highway, and the amount of highway tax otherwise raised. These combined form the township highway fund.

"The town superintendent of highways is in actual charge of the work. He hires the men and teams, purchases materials, directs the work and acts as paymaster, using vouchers which are redeemed in cash by the Township Treasurer, and which are retained by him as a receipt for money paid until the close of the fiscal year, when upon rendition of his annual report, and its acceptance by the town board, the vouchers are filed with the town clerk as a permanent record.

"These vouchers are furnished by the State Highway Department, and consist of a printed form with necessary blank spaces for the date, name of payee, date and amount of services rendered, or material furnished, and the road for which it was supplied. Each voucher is attached to a duplicate stub, to be similarly filled out and retained.

"The Treasurer is provided with an account book printed and ruled to receive an entry for each voucher paid, with spaces for sufficient particulars of identification like that on the voucher. Pages are provided at intervals for a recapitulated statement of vouchers paid, the data on which are finally carried forward to a single page and condensed thereon, forming an annual report of the receipts and disbursements required by law of all such officials. Blank forms are also provided for making duplicates of this report to the county superintendent of highways, the State Highway Commission, and the State Auditor.

"No other books or accounts are necessary for these two township officers in properly receiving, disbursing, and accounting for the highway moneys of any town. The township officials are pleased with this form of records, and errors and mistakes have been reduced to a negligible quantity.

"Partial audits of the highway accounts of any town are made by the State Highway Department at any time when it is deemed necessary or expedient. This prevents many errors which might otherwise occur, and unwise or extravagant expenditures are prevented, or checked if begun. An annual complete audit is also made, and it is found that the form prescribed greatly facilitates and simplifies the work of the auditor, errors, if any, chiefly occurring thru ignorance or carelessness."

CHAPTER XI

STONE ROADS

This whole text endeavors to show that sound principles of location, grading, and drainage must underlie successful road construction of whatever type, and whether the surfacing material be cheap or costly. This chapter outlines the essentials of broken-stone, or macadam construction, especially suggesting a cheaper form of building in which may serve as a successful gradation-type between cheap earth and costly macadam work. This would particularly apply to those communities favored with an abundance of stone, even tho supposed to be of inferior quality.

260. — When a State or county is ready to undertake the extensive construction of crushed stone or macadam roads, costing five to ten thousand dollars per mile, then such complete engineering supervision and control is to be assumed that it is not within the scope and purpose of the present work to deal with its details. Furthermore, there is an abundance of literature already available on this subject, — a sufficient reason for not attempting it here.

It is believed, however, that those who have pursued the present study up to this point will desire to have their ideas on the subject correct even if they are not comprehensive. The following outline of the subject is therefore submitted.

Macadam Roads. The macadam road is named from John L. Macadam, an English road-builder, who died about 1835. The word "macadam" now denotes a surfacing composed of angular broken stone bound together by, and whose voids are filled with, stone screenings flushed-in with water, and which is, by rolling, consolidated into a practically impervious crust. The surface and the sub-grade have a crown or slope from center to sides.

A good macadam road should have (1) proper location, (2) easy grades, (3) perfect drainage, (4) firm sub-grade or foundation, (5) broken stone possessing good wearing and bonding

properties, and (6) careful inspection during construction. Proper location and easy grades are more essential for macadam than for less expensive roads, because unless correct at the outset, they cannot be changed without great expense.

261. Sub-grade. — After a road has been properly graded and completed, the sub-grade may be formed by simply excavating a trench of width and depth equal to that of the compacted stone surfacing. Spongy material wherever encountered must be removed and replaced by good live earth or gravel. Where loose dry sand is encountered, care is necessary to prevent the sand from churning into the first layer of broken stone when rolling commences. On fills, if the earth has been deposited in layers and subjected to teaming, the sub-grade may be smoothed off and thoroly rolled. Enuf of the material may be piled along the sides or shoulders to form earth abutments to prevent spreading of the macadam when rolled. Too much care and effort cannot be given to solidifying and compacting the sub-grade or foundation.

The Stone. Trap rock, which is usually very dark-colored, fine-grained, and exceptionally hard and heavy, is the best stone for plain, or "waterbound" macadam construction. But local stone of poorer quality must frequently be used, and the Office of Public Roads, United States Department of Agriculture, tests samples from any locality free of charge.

Good road stone must be: (1) Hard enuf to wear well; (2) So tough and strong that the steam-roller does not crush it; (3) Possess sufficient bonding qualities in its dust (when wet) as to aid in maintaining a smooth, unyielding surface.

262. Construction. — The stone is usually placed in two courses. The lower course has sizes from 1½ to 3 inches in greatest dimension. If relatively soft, larger stones may be used than if extremely hard. Ordinarly a steam-roller cannot compact more than six inches of loose stone successfully, so the first course is rolled separately. The stone should be spread either from spreader-wagons or from dumping-boards. Careless dumping of the stone directly upon the sub-grade in piles causes an uneven finished surface, because of the greater packing of the stone at the bottom of the pile than is otherwise

obtained. The first course is thoroly rolled until walking over it does not loosen the stones. Teams hauling stone for the upper course should guard against cutting ruts or churning stone into the sub-grade.

When sufficiently rolled, a top-course of sizes from $\frac{3}{4}$ to $1\frac{1}{2}$ in. is then spread to a depth from 3 to 5 inches.

When it has been rolled until its surface is smooth and the individual stones are well keyed together and no creeping or waving appears before the front wheel of the roller, the bonding process is commenced.

363. Binder. — The bonding of a macadam road is accomplished by completely filling the voids in the broken stone with "fines" or screenings from the crusher. The process of binding, or bonding, requires the greatest care. The fines, or stone dust, should be worked into the road gradually. To accomplish this, they are spread in thin successive courses with alternate wetting by a sprinkling wagon and continuous rolling. Care should be taken that wagons drawing screenings do not cut up the partially-built road. When the voids are completely filled, mud will flush to the surface in front of the roller and the bonding is complete. If the macadam is well bonded, the road is now strong enough to withstand the kick of a boot heel, and when reasonably dry, is ready for traffic.

The width and depth of macadamized surfaces are governed by local conditions. A one-way road may be as narrow as 8 ft. The general practice is to build macadam surface from 14 to 16 ft. in width, but there should be earth berms or shoulders carefully maintained for an additional width of 3 to 4 ft. on each side. The thickness of the macadam surface is determined somewhat by the traffic conditions and varies from 4 to 8 in. when complete. Loose broken stone is usually estimated to consolidate from one-fourth to one-third under rolling.

A newly built or green macadam road sometimes immediately shows a tendency to ravel, particularly if the second course stone is trap or other very hard rock. This raveling usually cures itself but if continued, removal of the larger loose stones and additional rolling may be necessary.

265. Conclusions. — It should not be thought from the foregoing that the use of stone on roads is not to be thought of unless the county has the money to put into an expensive crushing and rolling plant, tho a stone crusher is relatively inexpensive, and the steam road roller of relatively recent invention. For fifty to seventy-five years macadam roads were successfully built when all the stone was broken by hand, and when the steam roller did not exist. Traffic was counted upon to consolidate the surface by steel-shod hoof and tire, and did so, when the stone was of suitable quality. The surface was maintained free of ruts and humps by constant attention, raking, and "tinkering" during the months when consolidation was taking place.

Given a locality which has stone of moderately good quality, there can be no doubt that a similar process can be carried out at a cost vastly less than the usual macadam construction. A road surface smooth and durable can be built and maintained provided only the persons in charge are willing to take the necessary pains with the work.

It is probable that the application of the stone under this plan should be gradual, as putting on a thick layer of loose stone might easily be a very serious detriment to traffic. This raises the question of a "modified" macadam, also, which in substance would be an earth road with a stone foundation, but it would be handled and maintained as an earth road, and not a stone road. All that is herein said about sand-clay, gravel, top-soil and other advanced types of earth roads should be thoughtfully studied in this connection by the student road-builder, to the end that practical and economical local combinations of the various methods may be put into practice. There will then be the greatest benefit to all interests, concerned. (See §§ 156–157 in this connection.)

CHAPTER XII

GRAVEL ROADS

265. Definition. — What is gravel? Outside the engineering profession the term "gravel" has not been very carefully used. Those who think in general terms often refer to any material containing upwards of twenty per cent grit or sand, as gravel. In country road work this may lead to confusion and disappointment.

The Engineering definition is:

> "Gravel consists of pebbles of various sizes, produced from stones, broken and then worn to smooth rounded corners. That they have been exposed for indefinite periods to atmospheric disintegration and mechanical wear, usually the rolling action of water, proves the durability and mechanical strength of the stone."

For road-building purposes it must contain a binder of sand, clay or marl.

266. Gravel as a Surfacing Material. — Authorities agree that suitable gravel for road-surfacing should meet the following requirements: The fragments should be too hard and tough to break readily under traffic. They should be so proportioned as to size that the voids will be a minimum, i. e. have varying sizes. They should be intermixed with some binding or cementing material to hold them in place.

The hardness and toughness of gravel varies greatly. The nature of its origin, however, may be taken as more or less of a guarantee of its durability, since the softer and more friable fragments have been worn away while being transported and deposited. Ordinarily gravel is not considered equal to the best crushed stone for road surfacing, tho some gravel roads very closely resemble the best water-bound macadam, and have proved to be very durable and lasting under medium country *traffic. Hence* where good gravel is found it has been widely

used in road improvements. In Indiana and Maine it is the principal road-building material.

267. Gravel Concrete. — By reason of its greater cheapness, usually, if available at all, gravel has also been extensively used in making concrete. Such uses are in concrete ends for pipe culverts, or entire concrete culverts. It is also frequently used for the aggregate in concrete for foundations, piers, and abutments under steel bridges. It has found a place, too, in all parts of the construction of reinforced concrete bridges. During the last few years, likewise, gravel has been extensively employed as an aggregate in concrete for road surfaces. It is also used in connection with bituminous or asphaltic surface treatments of roads, and has been used in the construction of asphaltic, or concrete surfaces. (See § 189 for Strength of Various Aggregates.)

268. Value of Gravel. — Enough has been said to indicate that the road-builder who has an ample supply of good, strong, hard gravel at hand, in a reasonably suitable mixture of coarse and fine grains and containing some good fine binding material, has a highway asset of great value. The student should search thoroly in the country surrounding him for deposits of this valuable material, and should submit samples of his findings to the instructor.

269. Properties of Gravel. — 1. The ideal gravel for the road-builder is a high-grade material, prepared in Nature's laboratory, requiring only to be properly placed and compacted on the road to produce an excellent surface. Unfortunately the ideal gravel is not always or perhaps frequently to be had. There may be a deficiency of binder, or an excess of sand or earth, or a poor grading of the sizes. These shortcomings can often be remedied. Adding 10 or 15 per cent of good clay sometimes makes a good road material out of an otherwise poor one. An excess of sand, earth, or large pebbles can be remedied by screening, while judicious mixing of gravel from different pits, or from different parts of the same pit will often greatly improve the quality.

2. The *shape* and sizes of the pebbles composing the gravel have an important effect upon its value as a road material.

To bond readily the pebbles should be angular and vary in sizes so that the smaller fragments will fill the voids between the larger pieces. River gravels are often deficient in this respect, as they are usually worn smooth and rounded and lack the proper grading of sizes. But if clay or other binder is mixed with well-graded river or creek gravel, the results obtained are frequently satisfactory.

270. — 3. *Sizes:* When gravel intended for the surface layer contains large pebbles, these should be removed or else raked into the foundation. Frequently they can be broken with a hammer by the man who does the spreading. At least 60 per cent of the weight of the gravel should be pebbles above $\frac{1}{8}$ of an in. in size. In the bottom layers 3 in., and in the top layer $1\frac{1}{3}$ in. diameter should be the maximum sizes. However, agreement with specified sizes is not found to be the essential feature. Thus in Maine they have surfaced with $\frac{1}{2}$ in to $\frac{3}{4}$ in. sizes. The binding material, such as clay, should ordinarily constitute from 10 to 15 per cent of the entire mass.

271. — 4. *Road Use.* The success or failure of a gravel road depends on the character of the material. There are three important qualities which the gravel should have — hardness, toughness and cementing or binding power. Of these three the last is usually the most important. This binding quality is due to the presence of oxide of iron, lime or clay, and to the angular shape and varied sizes of the pebbles composing the gravel. A dark-colored gravel is generally better for road-building purposes than the lighter colored ones. This is because the darker gravels are generally composed of material derived from the basalts, diabases and hornblende granites. These, as a rule, are materials well suited for road-building, as they possess hardness, toughness and good cementing qualities.

Caution. In hauling and placing gravel on the road care should be taken that the finer material does not separate from the coarser, as there is a general tendency for the finer particles to go to the bottom. It is often advisable to spread a thin layer of fine binder-material over the road surface after the gravel has been distributed and partially rolled. But too

Gravel road being built in Ohio.

Gravel road on 6 per cent grade in Maryland.

large an amount of binder on the surface of the road will make mud.

272. — 5. Before *placing* the gravel on the road the foundation and drainage should be prepared in practically the same manner as for a macadam road. The practice of dumping gravel promiscuously on the surface of the road and leaving it to be compacted by traffic is to be severely condemned. It produces a poor and rough road surface and entails a large waste of material, requiring an excess amount usually costing far in excess of what would be required to put the foundation in proper condition.

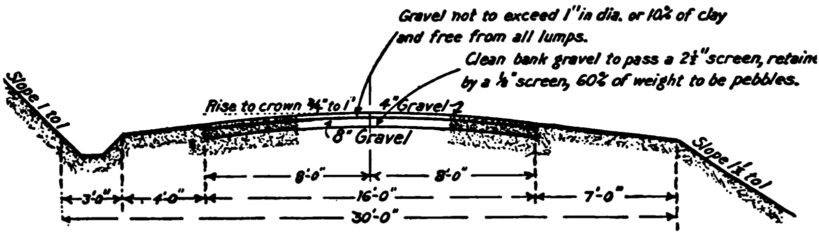
If the compacted depth of the gravel road is to be seven inches or more, it is best to place the gravel in two layers, each rolled and compacted thoroly. Loose gravel will usually compact from 25 to 30 per cent. (See § 283 for quantities needed.)

The construction of a gravel road takes *time* because the binding or cementing process is usually a slow one. The final completion of a gravel road may be said to be a "process" rather than a single operation.

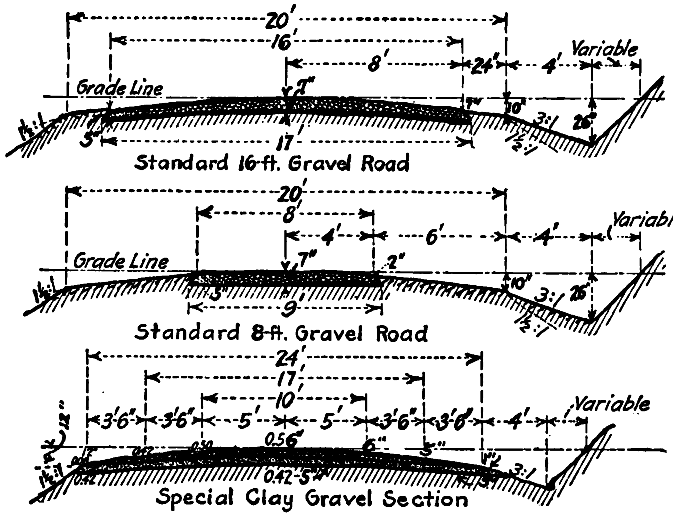
273. Maintenance. — Careful attention is needed during the first few months or possibly a year of the gravel road's life. The split-log drag or better, the "Road-Planer" (see § 161) can be used to smooth the surface, fill the ruts and maintain the crown. Large pebbles which appear on the surface should be thrown off or removed by hand rakes. While the road is being built a few loads of gravel should be dumped at convenient places along the road-side for later use in mending patches which tend to ravel or wear rapidly. After the gravel road has become thoroly bonded the maintenance requirements become very small under ordinary conditions of traffic, but prompt and proper maintenance must never be neglected.

274. Construction Methods. — In building a gravel road, beginning with the sub-grade, it is probably best to open a trench to receive the gravel, giving it the same crown or cross-section as the finished road will have. In the special gravel-on-clay sections as developed in Minnesota, however, no trench is needed. It has been found that gravel containing clay or

sand, or even loam, not exceeding 20 per cent of the entire quantity, makes excellent road material and will bind or compact readily. After the gravel has been properly placed on the sub-grade it should be thoroly sprinkled and rolled.



PENNA. GRAVELED SECTION —SIDE HILL



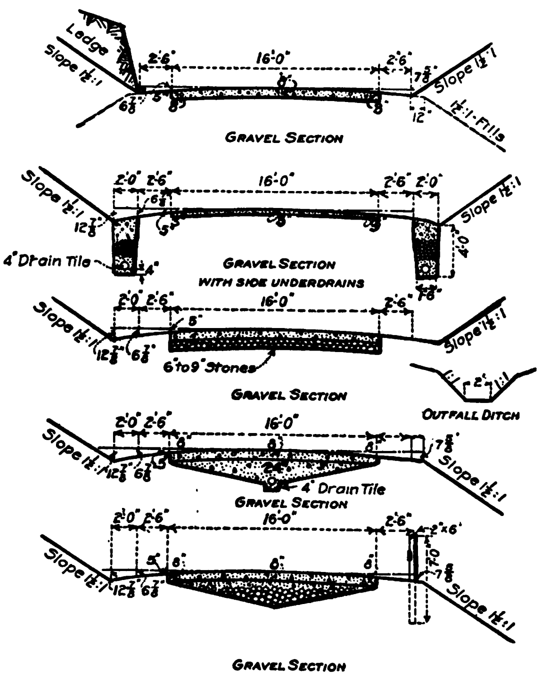
MINNESOTA STANDARDS OF GRAVEL

Where a gravel is deficient in binder, success has been attained by mixing clay with it on the road, using a peg-tooth harrow for mixing or dragging the clay into the gravel. Then a grader is used to smooth the surface, which is then thoroly rolled. Large stones are thrown out as fast as they appear on

the surface during the harrowing. Water is put on to soak up the clay in the binder, but not enuf to soften the sub-grade. The first course may consist of 3 in. gravel with clay binder and the second of $1\frac{1}{2}$ in. or $1\frac{3}{4}$ in. gravel topped with fine material.

275. — "In New Hampshire surfacing is accomplished by building the shoulders of other material and rolling enuf gravel to be 8 in. deep over the metalled surface of the road. The rough grading is left with a crown of 3 in. to $10\frac{1}{2}$ ft. (roads are 21 ft. wide) giving the gravel $10\frac{1}{2}$ in. depth in the center and 3 in. on the outside edge of the road. This reduces the average thickness of the metal but gives a gravel shoulder which is invaluable in the maintenance. It also gives a 10-in. depth for the 5-ft. strip in the center upon which the major portion of the travel comes.

"The gravel is usually laid in two courses, which assists in getting proper compactness, but it is not so imperative, provided the gravel is self-binding and the load is dumped far enuf ahead so that it must be completely forked and shoveled over. Where laid in one course it is easy to spread the gravel so that the larger stones are all in the bottom of the road, keeping ahead of the work in this way and leaving the surface composed of the finer material.



Standard Cross Sections for Gravel Roads in Maine.

"If a binder consisting of clay or marl is to be used two courses besides the binder should be laid. It is advisable to work the clay course thoroly through the top surface with a harrow.

"Frequently enuf rain falls to allow building the road without using a sprinkler. The summer of 1913 was extremely dry, and for a considerable time after completion the roads upon which no water had been used failed to 'come together.' A good soaking rain compacts a soft road readily, but where sprinkling is too expensive it is wiser to build without it.

"When funds are less plentiful, no shoulders are built, but successive thin layers are applied, after the road has been suitably graded. If each layer is kept smoothed up by dragging, harrowing, or rolling if possible, until it is thoroly compacted, before the next course is applied, a strong and substantial road crust is formed, not easily broken thru, or damaged, as will be true if too thick a layer is used

276. Cost. — "The cost of gravel roads varies widely. The pit price of gravel may be only 5 cents per cu. yd.; its cost is fixed by the average haul. With the material very near, the cost of gravel construction may not exceed $1,600 a mile, while with a 2-mile haul it may reach $3,500. Assuming grading and drainage expense to be $1,200 per mile, the total cost per mile varies from $2,800 to $4,800. The average of all gravel roads built in New Hampshire has approximated $3,900. Many of these roads are in remote sections, where the cost of the more espensive road would be far higher than the average in States where the railroad facilities are better. In Minnesota (1914) the average cost of graveling was given as $831.70 per mile, which included the cost of probably 1,000 cu. yds. of gravel. The average maintenance was $44.67 included in general repairs."

277. Avoiding Screening. — The expense of screening may be to a considerable extent avoided if there are good foremen in the pit and on the road. It will be possible to select material out of the different parts of the pit, and if the gravel lies in strata of different-sized pebbles, as it frequently does, it may be selected substantially as desired. There is a place in the road for everything that comes out of the pit, and the good foreman finds it. The strippings are used on the shoulders to raise grades, or widen banks, and material too large for the bottom course goes to make an extra course which serves as a foundation in low or muddy spots. Michigan recognizes the effect of the coarse material upon the type and quality of road produced by preparing standard specifications for 40 per cent and 60 per cent gravel, designating thereby material in which 40 or 60 per cent is in sizes between $\frac{1}{8}$ and 2 in. in diameter.

278. Binder. — The binding material found in, or added to gravel, may be clay, loam, iron oxide, silica or stone dust, resulting from the crushing under traffic or rolling of the softer materials in the gravel. Ordinarily a gravel which stands in a vertical face in a pit and has to be loosened, possesses good binding qualities and makes a good road surface. Many gravels do not have the right amount of binder and cannot be used without re-grading and mixing, and these must also have *the customary* care in spreading, rolling, etc. If too much

Gravel roads. — As built in Virginia.

Well-located road in Texas.

binder is present, it must be screened out; if not enuf, binder must be added. This is a matter that requires careful attention because many road-builders are too anxious for a gravel road to bind quickly. An excess of binder, if of a clayey nature, causes muddy roads during a protracted wet spell, or when the frost is coming out.

Roads surfaced with clean gravel, comparatively free from binding material, have been found well-bound after a few months traffic. This is due undoubtedly to the crushing under traffic of some part of the gravel, or to the production of fine dust by grinding or wearing off which has worked into the surface and acted as a binder.

279. Maintenance. — If, in a gravel roadway, a small depression appears and holds water in wet weather, it must be remedied promptly if a serious hole and its attendant repair expense are to be avoided. If the bottom of the depression is tight and firm, pick the material loose for an inch or so in depth before putting in new material to fill the depression. If, on the contrary, it is loose, clean out the old, loose stuff until the edges of the hole are nearly vertical, and throw it away; then put in the fresh material, tamping it well and covering it with finer sizes to aid it in packing down quickly. Always use for repairs, as nearly as possible, the same material as exists in the roadway adjacent to the place needing repairs. This is important for securing the subsequent evenness of surface and of wear.

Mr. Hooker of New Hampshire, previously quoted, says: "Under the patrol system a gravel road could be maintained in excellent condition at a cost of one-quarter of that of the higher types of roads." He believes, however, that the patrol system of itself is not enuf to properly maintain the highways. "The ideal system of maintenance uses a repair gang or a flying squadron, who should do the preliminary work in the spring necessary to put the road in good condition before turning it over to the exclusive care of the patrolman.

280. Maintenance of Gravel *versus* Macadam. — He continues: "The special advantage in maintaining gravel roads consists in the adaptability of the road drag or hone to this work, the availability of the material for repair and the low cost of resurfacing. With material fairly available the cost of 4 or 5 in. of gravel upon the road will not exceed $500, and with a patrolman on the road such resurfacing will not be required within eight or ten years after construction. The yearly resurfacing charge, as distinct from maintenance, will be then only $50 or $60 per mile, while the resurfacing of various types of macadam roads will probably

require at least ten times that amount. The patrol cost will not be more than $100 per mile nor the repair gang $50, so that the total maintenance charge over a series of ten years will not be more than $200 per mile. The foreman of the repair gang on road work should have sufficient knowledge and experience to justify spending his entire time in supervising and planning the work without attempting to labor with his men. The element of thoroness in details, such as complete cleaning of mud holes, sufficient material, swift repair of water breaks, etc., cannot be overemphasized. There is always enuf necessary planning and supervision to keep a good road foreman occupied."

It is desirable to keep a little loose gravel on the road surface, if necessary, in order that severe scraping operations, tearing up compacted surface to secure material to fill little ruts and depressions be not necessary. Systematic dragging after rains, continued repairs by using fresh material on the little defects, and a sparing use of the scraping grader, — these are the secrets of successful gravel-road maintenance.

281. Sand and Gravel Deposits. — The enormous use of concrete in engineering construction and road-building has markedly developed two collateral industries, — quarrying and stone crushing, and the utilization of sand and gravel deposits. The old idea dies hard that the rough surface of broken stone makes a substantially stronger bond with cement than the smooth surface of water-worn gravel, notwithstanding that numerous tests have proved the perfect bond of cement with smooth gravel.

It is now realized, too, that for reinforced concrete work a good gravel runs around reinforcing bars better than broken-stone concrete. Where clean gravel is obtainable at a low price, there is every reason why it should be used by the engineer. In concrete-road construction, admittedly the most severe service to which concrete is now applied, a large proportion of the concrete roads thus far constructed have been built with gravel aggregate.

282. — For concrete and road-building purposes the exact characteristics of Oklahoma's sand and gravel deposits have not been particularly investigated. A few progressive states are showing a lively activity in this direction, however. New York with its hundred-million road-bond issue, now being

spent, conducts a vast number of tests of three road materials, and from the records, is building up a road-material map of the State, of constantly increasing usefulness.

It should be one of the first tasks of a State Highway Commission when given the means for doing so, to locate and classify these deposits as fast as road work was projected near any of them. When an improved road project comes up one of the first things to be done should be a systematic and thoro search for sand, clay, gravel, or mixtures of these materials in that neighborhood, or within a reasonable power-hauling distance. There can be no doubt that considerable sums of money spent in such investigation would be an excellent investment, for with suitable materials discovered and available the advantages of stone roads might be had at perhaps a fifth of their cost.

282a. Quantities Needed. — As previously discussed, there are three general classes of roads: the main inter-urban highways, the principal market roads and the branch rural roads, including those in sparsely settled sections. For the first class, a standard width of 24 ft. roadway for sub-grade is recommended with a minimum surfacing 16 ft. by 6 in., requiring approximately 1600 cu. yds. of gravel per mile.

For the second class, of greater mileage, a standard width of 20 ft. sub-grade is recommended with a minimum gravel surfacing of 16 ft. with a thickness ranging from 6 ins. in center to 1 in. at the sides. This requires approximately 1,200 cu. yds. of gravel per mile. The additional cost of placing gravel to a width of 16 ft. instead of 8 ft. as was formerly the custom, is more than offset in the maintenance costs, for a better distribution of travel is obtained and dragging may be done without damage to the surfaced portion.

The third class of roads might well be constructed with a traveled roadway of 16 ft. and graveled 8 or 12 ft. Such roads, however, should only be constructed where travel is extremely light, with practically no motor vehicles.

The Good Roads Year Book (1914) gives the following quantities per mile for 10 ft. of width. Quantities for other widths may be proportioned from this.

GRAVEL PER MILE, 10-FT. WIDTH

Thickness Compacted Inches	Cubic Yds. Compacted	Cubic Yds. Loose
6	977.7	1466.6
7	1140.7	1711.1
8	1303.7	1955.5
9	1466.7	2200.0
10	1629.6	2444.4

CHAPTER XIII

SAND–CLAY ROADS

Two road-building materials, sand and clay, each possess qualities that largely offset the poor qualities of the other. Sand is loose and incoherent; clay is unctuous and sticky. Put the grittiness of one against the plasticity of the other, mix, mix, mix, . . . then smooth the surface, pack it down, and the result is a road surprisingly hard, strong, and smooth. It is called a *sand-clay* road.

This chapter gives the details of numerous variations on the plan thus broadly outlined. It also goes fully into practical tests of these materials, whose aim is to learn whether they promise satisfactory results. Plainly it is wise to do this testing in advance of spending large sums in full-scale experiments on the roads. The usual costs are indicated.

283. The Sand-Clay Road. — Sand and clay are the two most universally distributed ingredients of natural soil, occurring either separately or mixed by nature in various proportions. A sand-clay road is a type of scientifically constructed earth road. It is an earthy hardpan produced or improved by the skillful combination or manipulation of sand and clay. The principle of its strength is that a mechanically interlocking aggregate of sand or gravel is cemented together by an adhesive earthly binder. The stronger the sand or gravel is, and the better natural bond it has the more durable the road, and the less its cost of maintenance.

Within the past decade the sand-clay surface for country roads has been very generally adopted thruout the Southern States where the materials are available. This type of surface generally appears to fit the traffic and climatic conditions and to meet the requirements of low first cost which distinctly rural and thinly populated districts demand in road construction. It will not stand a dense steel-shod traffic.

284. The Value of Sand-Clay Roads. — The sand-clay road is of recent development and its value is not universally understood. Its cheapness makes it desirable as its original cost

is roughly only from one-eighth to one-third as much as that of macadam road. It is easily kept up and is easily renewed. Its surface is in a considerable measure "self-healing." The materials are widely distributed and are usually to be obtained where stone is lacking or at so great a distance as to render the cost of transportation prohibitive. The construction is able to support in weight any sort of country traffic. It is very solid, only slightly dusty in dry weather and never very muddy.

285. Theory. — Sand is a bad road material because it possesses no cementing properties, and its particles are free to move about each other. Clay forms a plastic, sticky mass when wet. An excess of water in sand makes it soft and "quick," but just enough water to fill the voids or open spaces between the sand grains renders it quite firm. The object of the sand-clay road is to bring about a condition where clay, like the water, just fills the voids in the sand, leaving the corners of the grains touching each other. The clay then prevents the sand grains from moving freely over each other when the mixture is dry, and the bracing against each other of the sand grains prevents the mixture from becoming soft and plastic when wet. If too much sand is present, the clay cannot keep the grains separate and the mass will behave like sand when it is dry. If there is too much clay the sand grains become entirely separated and cannot reinforce each other and keep the mass from becoming plastic when wet. The correct proportion is difficult to ascertain except by trial.

286. — True Clay and "Colloids." — The University of Georgia laboratory defines "true" clay as that portion of the sample which remains in suspension after settling for thirteen minutes through water $3\frac{1}{2}$ inches deep. It is removed by repeated washing, settling, and careful siphoning off. Most natural clays are impure and contain large percentages of coarser materials such as sand, mica, and silt. They vary greatly in plasticity and in the expansion and shrinkage under the action of water. The true clay contains an extremely fine portion called "colloidal" clay, which is very glutinous or gummy. The coarser clay has less gumminess. It is thought

that the binding value of the clay depends largely on the amount of fine colloidal ingredients. In dry weather, this gives great adherence, but unfortunately in wet weather the colloidal matter softens quickly. It is probably one of the chief causes of the high expansion of certain clays when wet.

287. — The argument would then be that a clay too rich in colloidal matter when used in a sand-clay mixture softens too readily and by swelling tends to break the interlocking strength of the sand grains. The larger the total amount of clay the greater the expansion. The most desirable kind of clay would be that which has a rather low colloidal percentage to meet wet conditions but yet enuf to bind firmly the sand grains in dry weather. It is also desirable that the total of real clay should be as low as possible consistent with adhesive strength in dry weather to avoid expansion effects. This also points to the value of a closely-graded sand mixture with a minimum of voids, thus requiring a minimum of clay.

288. — Slaking and Shrinkage of Clays. — Mr. Gearhart, of Kansas, points out that a discussion of clay properties should not be dismissed without particular reference to these qualities.

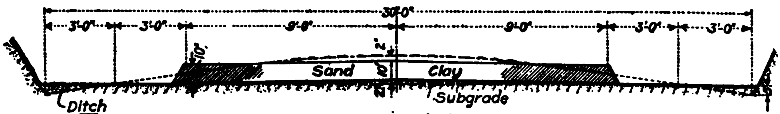
"While laboratory tests help us to know what to expect, the best check comes by building only a few miles of road at a time. This is a practical test of a clay's worth. The properties of greatest importance in road construction are plasticity, and the property of slaking when first wet. The most plastic of these materials are technically called 'ball clays.' A lump of such clay immersed in water will usually preserve its form a considerable time. Non-slaking clays, altho very sticky when wet, readily mix with water. Some other clays, however, will immediately fall to pieces when immersed, due to the rapid absorption of water in the pores. These are slaking clays and mix easier with other materials than the more plastic ball clays. This is of course an advantage for road building, but they often have inferior binding power.

289. — "There is still another physical characteristic of clay vitally important for roads. Many clays shrink when dry. This shrinkage is the measure of expansion which renders the sand-clay mixture unstable. When water removed by evaporation is restored to the sand-clay mixture it causes expansion which separates the grains of sand. This property is inherent in the clay and cannot be overcome, but by using less clay its destructive action can be lessened.

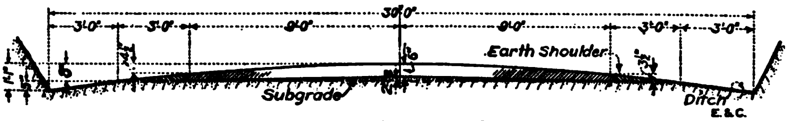
The best kind of clay for road work is one which slakes easily enough to enable the lumps to be readily broken up. At the same time, without being too plastic, it has sufficient binding power to cement the grains of sand and form a smooth, impervious road surface. The available materials should therefore be tested to secure a clay with the least possible shrinkage."

290. Sand-on-Clay. — To build such a road upon a clay sub-soil, requires it to be thoroly drained and the foundation to be properly prepared. Surface water must also be carefully provided for, and the grade should not exceed four or five per cent. The surface of the sub-grade should be plowed and harrowed to a depth of about four inches until completely pulverized. It is then covered with six or eight inches of clean angular sand.

The materials are best mixed while comparatively dry, tho it has been common to do the entire mixing and puddling with the materials wet. It is, however, a difficult matter to



Cross Section of Surfaced Sand-Clay Road Before Consolidation.



Finished Cross Section of Surfaced Sand-Clay Road After Consolidation.

mix the sand evenly with the clay if the latter is soft and cut into ruts by travel. Though the preliminary dry mixing is desirable, often conditions do not allow it and the sand has to be mixed on the wet clay road. After this first mixing has been finished the road is puddled, reshaped, and reworked if necessary afterward, using any method which appears most practicable to shape-up, smooth and compact the surface.

In case an excess of clay works to the surface, tending to make the surface sticky when wet, sand should be applied until this trouble is overcome.

291. — When completed the sand-clay should be from eight to twelve inches in thickness, depending on the sub-grade or foundation. With a hard clay foundation, eight inches will suffice. If the foundation is sand, it is well to put on as much as twelve inches of surfacing material. After a few hundred *feet of surfacing* material have been placed, a grading machine

should be run over it to smooth and crown the road before the top becomes too hard.

After the first heavy rain the road should be harrowed and then dragged, or, preferably rolled. The mixture should now begin to set and become hard and firm and the road may be supposed to be completed, though it should be carefully and frequently inspected for a few weeks afterwards. Sand should be added to places which soften by rain, and clay of good binding power is needed wherever the road loosens in dry weather.

292. Traffic Method. — In many instances the sand has been spread over the clay road and traffic alone does the mixing. This method has given satisfactory results, but it is not recommended as the best because it takes a much longer time and often there is not a thoro mixing of the two materials.

293. Clay-on-Sand. — In this method clay is hauled upon a properly prepared, shaped and graded sand foundation and mixed with it. The mixing process must be thoro and is carried on by plowing, harrowing, in fact by any means that will effect a thoro incorporation of the two materials. Experience has shown that applying sand successfully to a clay foundation is easier than the opposite process. Since the foundation is sand, a little more clay will be necessary than where the foundation is of clay or soil. If the clay is very pure and plastic a less amount will be needed than if it is lean or sandy. After applying a suitable layer of clay, then a layer of sand, usually dragged on from the sides, should be placed upon that, and the mixing begun. After a heavy rain the road should be again harrowed and shaped up. The first mixing should be dry, if possible. If too much clay has been used the road will be muddy and sticky when wet. Spreading more sand, however, will remedy this.

294. Time and Patience. — A sand-clay road, unlike other roads, cannot be finished in a short space of time. It can be left in an apparently finished condition with a hard, smooth surface, but the hard surface in reality may be only a crust, over perhaps several inches of loose material. After the first hard rain, the crust softens, the road will probably get bad,

and the work appear to be a failure. This, however, is just what is needed to make it eventually good. When the surface has dried until the mass is in a plastic state it should be dragged smooth, and again given a proper crown. It should be kept this way by dragging it at least once a day until the sun has baked it hard. It is a mistake to keep traffic off during this process. The tamping of the wheels and hoofs is needed to compact the sand-clay into a homogeneous mass, and the ordinary roller is not very effective in this work. It would appear that a tamping roller, such as has been used in the construction of oiled roads in California, should be very effective for this purpose.

295. Dust. — The quantity of dust raised on a sand-clay road by an automobile depends largely on the amount of clay and general excellence of construction. If it is well constructed and of good materials, it will yield from one-fifth to one-tenth of the dust raised on a water-bound macadam road under the same conditions. An excess of clay will yield dust. Also, the road will tend to ravel and then become dusty, if the clay is of poor quality or deficient.

296. Quantity of Sand or Clay. — The quantities necessary to add to a sand sub-soil, and of sand to a clay sub-soil will be of interest.

If the road-bed is nine feet wide on a sandy sub-soil and the clay is added to a depth of six inches, it would require 880 yards of clay to cover a mile of road. For a 16-foot road it would require 1,574 cubic yards of clay. If it is a first-class plastic clay, free from sand, and only 4 inches of it were needed; this would require 587 cubic yards for a mile of 9-foot road, and 1,049 cubic yards for a mile of 16-foot road. If the road-bed has a clay sub-soil and sand is added to a total depth of 8 inches, it requires 1,173 cubic yards per mile for a 9-foot road, and 2,085 cubic yards for a mile of 16-foot road. These figures are subject to some modifications, depending on the nature of sand and clay used.

297. Summary of Established Practice. — *Clay Base:* 1. Have the top of the clay grade smooth and about four or five inches lower than it will be when finished.

2. Plow and harrow the top for the width the sand is to be put on, leaving it loose but smooth, with no big lumps.

3. Spread evenly about four inches of sand over the top, *plow and harrow.*

4. Spread four more inches of sand over the top and harrow and drag thoroly.

5. Use clean coarse sand, even if it has to be hauled some distance.

6. When possible, harrow just after a rain.

Sand Base:

1. Smooth the sand road, leaving it perfectly flat.

2. Spread the clay the desired width and from four to six inches thick.

3. If the sand base is clean sand, drag it up on the clay for a thickness of four inches and plow, harrow and drag thoroly, preferably after a rain.

4. If the sand base contains loam, haul clean sand from a pit.

5. Use natural sand-clay mixture in preference to pure clay.

298. Natural Sand-Clay Mixtures. — If natural sand-clay mixtures are available locally, but are not suitable for use alone, because of a deficiency in either sand or clay content, the defect may be corrected by adding the proper quantity of either material. This method of treatment is generally more economical than building up an entirely artificial mixture, using sand as a base, adding the proper quantity of clay, and mixing. Occasionally it may be possible to successfully combine two natural mixtures in which an excess of sand appears in one and of clay in the other and trial mixtures made until a strong road material results.

299. Modified Natural Mixtures. — The advantage of using a natural sand-clay as a basis for artificial mixtures lies in the fact that the two materials are already somewhat thoroly mixed, and the incorporation of the additional sand or clay will be more easily effected than when making a purely artificial mixture. In the latter case, the clay tends to form in clods and balls and thoro incorporation of the two is accomplished only after a long-continued process of puddling and working.

300. Wintering. — Information is lacking in regard to climatic effects on sand-clay roads, especially in the north. But there were more than 24,000 miles of sand-clay roads in the

United States in 1909 and more than a third of these were in the northern states. Undoubtedly there is no great damage done by frosts or the northern roads would suffer considerably.

301. Georgia Top-Soil Roads. — The use of natural mixtures as a special type of sand-clay road has been developed to its greatest excellence, perhaps, in the state of Georgia, tho Alabama, Virginia and the Carolinas have made notable progress in this direction, also. During the past seven years the University of Georgia has been studying, observing and testing sand-clay roads and the materials for making them in that State. It finds for example that the average cost for 16-foot wheelway laid 10 inches deep may be placed at $500 per mile.

302. Results. — It is, of course, found that the sand-clay surfaces are of varying efficiency, but that any suitable road soil (meaning a natural sand-clay mixture or "top-soil," which they often find in the cultivated fields adjacent to the highways) does away with the two great traffic enemies, deep sand and deep mud.

The better grades, usually carrying coarse sand and gravel, give a surface too hard to cut with the heaviest road machinery and are capable of supporting the heaviest loads after long rains, are free from mud or excessive dust, and uninjured by automobile traffic in both wet and dry weather.

The medium grades carrying medium sand and less coarser gravel are firm and hard but can be cut by heavy road machines; are somewhat softened in long rainy spells but do not cut deeply, and are somewhat dusty in dry weather.

The soft grades carrying chiefly fine sand are firm and strong in dry weather, are subject to washing and softening in heavy rains, and can be resurfaced with light metal or split-log drags. They usually show a lack of balance between sand and clay and mark the lower limit of suitable road soils.

303. — The characteristics of the so-called top soil mixtures are rather indeterminate, varying from a sand-clay thru all gradations to an excellent road gravel.

It is found, in general, that these "top-soils" are a fairly

well-mixed and uniform mass of gravel, sand, and clay, ready for use without further intermixing; that they pack down promptly under construction teams and traffic; that even where freshly laid, the mud in rainy weather is not deep and sticky; that after a rainy spell the roads dry out promptly, then harden and do not soften materially under subsequent rains. These are some of the reasons why the method has commended itself to both county authorities and the public.

304. Methods. — *First:* The road bed is graded to a width of 30 ft.

Second: In the center a bed of top-soil 10 in. deep and 16 ft. wide is laid. The teams haul over this bed as the work progresses. With clay foundation no trench should be prepared to receive the top-soil.

Third: The road machine excavates flat side ditches 6 in. deep and 4 ft. wide, throwing the earth as a shoulder against the top-soil bed, and then crowning the whole from ditch to ditch.

Fourth: The construction teams and traffic pass over the green bed and pack it down chiefly in the center. When several hundred yards are thus partially packed, the road machine pulls in the material from the sides and resurfaces the bed. New top-soil is delivered upon weak places and the whole shaped up.

Fifth: As fast as the sub-grade is made ready the top-soil layer is spread on it. Thus by the time $\frac{1}{2}$ mile of road has been graded and covered with top-soil, the first $\frac{1}{4}$ mile has undergone considerable packing and resurfacing and is getting into good shape.

Sixth: For some weeks close attention is paid to the new bed, watching for weak places, doctoring them, maintaining the grade with new top-soil and keeping the crown fully up to 1 in. per foot.

Seventh: Wet weather hastens the period of consolidation if followed by a dry spell. When packed quite wet, the wheels consolidate the material from the bottom upward. In dry or moist weather, the top layer only is consolidated and may cut thru at the next rain. A period of wet weather is usually

necessary for a full packing down of the top-soil into permanent firmness.

Eighth: Usually in two months a new top-soil road-bed is consolidated, shaped into its correct crown, and able thereafter to withstand the rains and traffic.

305. Cost. — The cost per mile to Clarke County, Georgia, of putting on a top-soil coat is estimated as follows, using convict labor at 50 cents per day and the county teams at $1 per day:

2,600 cu. yd. top-soil, hauled 400 yd., at 10 cts.	$260.00
2½ acres top-soil, purchased at $30	75.00
Side ditches, shaping, etc., during consolidation	65.00

This county has virtually abandoned the construction of macadam roads in favor of the top-soil road. These were for metal surface 14 ft. wide, costing $4,000 per mile. The interest charge for one mile of macadam road will build ½ mile of the top-soil road. That the maintenance of the top-soil road by machinery is very low and that the life of a 10-in. bed with high crown will be at least five years and probably longer before renewal, emphasize the financial wisdom of the change of policy. Other road costs were (Georgia, 1913):

Athens-Jefferson Road, $318 per mile, took 300 cu. yd. material (loose) or 10.6 cents per cubic yard. Convicts at 50 cents per day, and teams $1 per day.

To this add $80 if average haul is one-half mile; and add $240 if haul averages 1 mile.

Another mile took 2,000 cu. yd. average haul 900 ft. or at a cost of 12.7 cents per cubic yard for material, labor costs as before.

An artificial mixture of sand-clay-gravel cost $475 per mile, labor as above, took 2,700 yd. material, average haul 2,700 ft., cost, 17.6 cents per cubic yard.

306. Essentials of the top-soil method as now practiced are:

First: The selection of a top-soil containing 50 per cent or more of hard, coarse residue, avoiding highly micaceous or soft organic soils and using sticky clay as the binding material. It is preferable when the ingredients are uniformly mixed by the farmer while cultivating the land.

Second: Use a thick layer, 10 in. to 14 in., according to the character of the foundation, to avoid cutting thru into the clay foundation and to allow for wearing down.

Third: Use a high crown, at least 1 in. per foot. As the center wears off, the road machine dresses the bed down to a low crown. There is enough sound material in the high bed to make the difference. The material best suited for surface work should be reserved for that purpose, and the inferior material may be used to make the fills, which are then covered with selected surface material. In handling dirt in this manner, the initial cost is increased, but the results fully warrant the small added cost.

307. Virginia Specifications and Conclusions.—

(Extracts): "All stones over 3 in. in diameter are to be thrown out. The soil on the road, when completed, shall be 10 in. thick in the center, tapering-out at 10 ft. from the center, except in cases where in the opinion of the engineer these thicknesses should be increased or diminished. The surfaced roadway is to be 20 ft. in width."

"The soil is to be kept in position on the roadway by a road machine, or other means satisfactory to the engineer, until it has been thoroly wet down to the sub-grade. The soil or surfacing is then to be reshaped and dragged with a split-log drag until it is thoroly dry and has set or hardened true to the specified cross-section.

"The finished road should have a crown of not less than ¾ in. to the foot and not more than 1 in. to the foot."

308. — Their Engineers also report that the road should not be considered complete the first time the surface is put in good shape. Bad sections may develop after the surface has been in shape even one year. The real tests for such a road are protracted droughts and long-continued, slow, drizzling rains, followed by freezing, which is very trying, and the best road will probably require some dragging after such weather. If well-built, a split-log drag used when the top is dry enuf not to stick and still wet enuf to pack will put the surface in good shape again. If not worked when plastic the drag must give way to hard labor with pick, rake, shovel, and hand-tamper, all used "judgmatically." In sections where the sand-clay or soil roads have been built the large increase in taxable values will probably provide a sufficient fund to resurface with as good or better material within a few years if necessary.

309. "Organization and Equipment. — An equipment for one force consists of 16 to 20 mules, one 6-horse grader, one 2-horse grader, one rooter plow, one 4-

horse turn plow, one 2-horse turn plow, about seven wheel and drag scrapers, one wagon with slat bottom for each 2-horses, one heavy disk harrow and one split-log drag for every four or five miles of road to be constructed, one spike-tooth drag and small tools, such as picks, shovels, etc. An equipment of this size will cost about $6,000. Two foremen and 20 to 30 laborers are usually required to operate this equipment, and the cost per month will average about $1,500. A force of this size will build from one to three miles of top-soil road per month. In Virginia, where the convicts are furnished by the State free of cost, the cost to the counties will be about one-half of the above."

"*Cost.* — For about 270 miles of top-soil and sand-clay roads built in Virginia during 1913 the average cost was $883.32 per mile."

310. General Comments. — "These Georgian roads near cities are generally 35 and 40 feet in width because of heavy traffic conditions. As the traffic decreases further out, the width is reduced to 30 feet and the materials are sand and clay instead of gravel. The practice is to use these materials for a minimum depth of 12 inches and to thoroly mix by plow, harrow, and road machine. When finished, roads are packed by rain and traffic, during which period the drag is constantly used to preserve a symmetrical contour. Roads so built show practically no effect from heavy rains. Reinforced concrete bridges and culverts of ample size are used on all permanent construction, the policy being to eliminate wooden bridges.

"As a result farmers are hauling five or six thousand pounds to a pair of mules where the previous load limit was 1,500 to 2,000 pounds. Another result is that land values on all improved roads have increased from ten to twenty dollars per acre, and the people who live in the city are buying country places for their own use. The auto enables them to reach town for distances of six miles or more as quickly as a surburban street car."

311. Recognizing Natural Mixtures. — If a good natural mixture can be found a great deal of labor and expense is avoided. The most important point is to recognize such a mixture when seen. It may usually be noticed in any section where clay and sand are found. It may crop out well up in the hills and have in ditches and cuts the appearance of sand-

stone. A really good stratum of well-mixed sand and clay will stand perpendicularly in cuts and ditches, resisting erosion almost as well as soft sandstone.

312. Testing. — A test of the best natural sand-clay mixtures will show the sand to be about 70 to 80 per cent of the whole. The test is simple. Take an ordinary medicine glass, measure two ounces of the material and wash out the clay. Dry the remaining sand and measure again in the medicine glass. The theory of the sand-clay mixture as a good road material is that the clay fills the voids between the grains of sand, firmly binding them together, while the sand forms the wearing surface. If there is not some such proportion of binder poor results are probable.

A *washing test* of Georgia top-soil samples has been performed as follows: The sample was measured in volume, then washed in running water until all the clay, mica and light ingredients were washed away, leaving the heavy sand and gravel. The volume of this was then measured. The samples were taken from the same points furnishing top soil for the roads. Ocular inspection had shown that they were highly charged with coarse material, and that while containing some mica, the clay present was well in excess of mica, and was of a sticky quality. The percentages by volume of the heavy residue ran from 40 to 65. The roads built from them had proved satisfactory.

313. Test for Voids. — The approximate proportions to be used in a sand and clay mixture may be determined by filling a vessel with a sample of the sand, and a similar vessel with water. The water is poured carefully into the sand until it overflows. The volume of water used represents roughly the proportion of clay needed. Ordinarily from 10 to 15 per cent of clay and from 85 to 90 per cent of sand constitute the proper mixture. The proportion of sand and clay can best be determined, however, as the work progresses, since the clay often naturally contains some sand.

314. Slaking-Ball Test. — Tests of value in preliminary investigation and in determining correct proportions during construction and after completion of the work are summarized here.

Typical samples are taken both of sand and clay. Mixtures are made, ranging from 1 part sand to 3 parts clay, up to 3 parts sand to 1 part clay, as the materials appear to warrant

it. These mixtures should be made to vary by one-half of 1 part, 1:3, 1:2½, 1:2, etc., 1½:1, 2:1, 2½:1, etc., and should be worked up with water into putty-like masses.

From each test, take a small sample of from 1 to 2 cu. in. cut out with a small measure. A small medicine glass, or even a large brass thimble is handy. It is essential to get equal samples of each test mix. These samples are then rolled between the palms of the hands into reasonably true spheres and placed in the sun to dry. Marks may be scratched on them. When thoroly baked, they are placed in a circle in a flat dish and covered with water, avoiding pouring water on the samples. Slaking begins at once and proceeds at different rates. The sandy specimens will break down first, those with excessive clay will disintegrate second, and those having about the proper proportions will act more slowly. Usually, there will be one or two that determine the proper proportions of the materials, and these usually lie together in the series.

Rubbing Test. — Another test of some value can also be made on the *dry* spheres. Lightly rubbed with the thumb, those having too much sand will break down rapidly. Those having too much clay will soon begin to "dust" away, while those having the most stable mixtures will assume a slightly glazed effect under the rubbing, due to the moisture and oil of the skin.

These two tests will not give the same results. The dry test will indicate a mixture richer in clay as the better one, and the wet test will indicate a sandier mixture. The sample indicated as satisfactory under the wet test that lies between the other two will prove best in service. These tests do not determine the absolute sand or clay content of the mixture, for the clay selected almost always contains sand, and the sand, in most cases, contains silt or clay. The tests serve, however, to fix the actual values of the mixture in the pit run, as represented by the samples.

Clay: Thumb Test. — An almost absurdly simple test, but one yielding valuable knowledge is this: wet the thumb and *place it* against the clay. If it sticks to the thumb it is of the

right quality for making a sand-clay road. If, on the other hand it does not stick, we are safe in assuming that it will not make a good binder. In general, select the stickiest clay and the most sharp and coarse sand available.

315. Gypsum-Clay Roads. — Of special interest to the western part of Oklahoma, Kansas, and other states similarly situated is the possibility of combining the sand of their sand-hill regions with some form of the gypsum widely distributed there also. The following is extracted from a report upon an experimental road built in 1909 by the United States Office of Public Roads at Garden City, Kansas.

"In the semi-arid portions of Kansas, Nebraska and Oklahoma there is an extensive area of sand hills. These hills are usually parallel to the rivers and vary in width from a few hundred yards to several miles. They are continually shifted by the winds, and hence road building in this region is a difficult problem. Good road material is scarce and the country is sparsely settled. In many localities there are no road materials except an alkali soil, gypsum clay, or a gumbo-like sedimentary clay.

316. — "At Garden City, Kansas, the sand hills run parallel to the Arkansas River. A careful inspection of the vicinity revealed no available road material except occasional deposits of gypsum clay distributed irregularly across the sandy belt. From one of them the material used was taken. The farther down in the pit the stickier the clay was and the better it compacted after adding sand.

"The problem was to find the best method of handling the local material, *Gypsum Clay*, to produce a road with a wearing surface capable of resisting the action of the constant winds, generally from the south. For this experiment a section of road 765 ft. long, situated on the slope of a sand hill, was selected.

317. — "The clay was hauled directly upon the road, for a width of 12 ft. spread to a depth of about 9 in., the hauling moving over the loads previously deposited. All holes so developed were filled at once. Ordinary traffic was allowed upon the road and this compacted the clay firmly. During the time of hauling the clay no rain fell, but after the hauling was completed a heavy rain thoroly soaked the clay. While the road was wet a spike-toothed harrow was put on and the clay completely pulverized. Then five furrows were back-furrowed on each side of the clay, thus raising the sand shoulders above the clay center. A split log drag was now put on the road and the sand thus raised by plowing was pulled from the shoulders upon the clay and thoroly incorporated. The road was then smoothed and left for travel.

318. — "The construction of this road followed closely the ordinary method of sand-clay construction. A surface was necessary which would resist the occasional heavy showers incident to this climate and at the same time resist the action of the winds. Therefore, the clay having the greatest tenacity was selected. Because of the dryness of the climate it was deemed best to proportion the clay far in excess of the sand. While the clays available may not be altogether desirable, still any clay that will pack under traffic will improve greatly the heavy sands found in this locality."

319. The Cost Data of this experiment follows:

	Total	Per cu. yd.
Stripping clay in pit	$ 7.17	$0.024
Plowing up clay in pit	10.50	.040
Loading clay into wagons	33.00	.129
Hauling clay to road	39.50	.154
Spreading clay on road	10.00	.037
Sanding, harrowing, and finishing road	2.33	.009
Cost of clay on road per cu. yd.		.40

The cost per square yard of part clayed was 10 cts. and the rate per mile $707.45.

320. Kansas Sand-Gypsum Roads. — Mr. Gearhart, State Engineer, said in 1910,

"The first Sand-Gypsum road in Kansas appears to have been constructed in 1892 near Kinsley in Edwards County. Here gypsum is found in large quantities in the flats and sand-hill beds. It is about 1 part gypsum to from 3 to 5 parts sand, resembling a sand-lime mortar of the same proportions. In some of the beds large deposits of gravel are found with the gypsum which add very much to its road-making value.

"From 1892 to 1902 a total of 25 miles were built, all 16 ft. wide. The gypsum was placed 8 in. deep in the middle and about 6 in. deep at the sides. The average haul of the gypsum was ½ mile. Three dollars per eight-hour day was paid for teams. The traffic did the mixing and the cost was $350 per mile, probably including donated labor. The cost of maintenance with a King drag is $10 per mile per year. Before the roads were treated 50 bushels of wheat was the maximum load for four horses. Now 100 bushels can be hauled with ease.

321. — "In 1905 and 1906 4½ miles of sand-gypsum road were constructed south of Syracuse in Hamilton County, Kansas. This road is 16 ft. wide and the gypsum was placed 8 in. deep. Teams at $3.50 per day; average haul, three miles. Mixed by traffic, the cost was $500 per mile with probably some free labor, or 5.3 cts. per square yard. Maintenance with the King drag is $5.50 per mile per year. In dry weather the surface grinds up some and blows away. This trouble can be overcome, doubtless, by treating the surface with a good grade of road oil, tho the alkali may injure the oil considerably, as shown elsewhere.

"Immediately after a rain the road is rather slippery, but this can be eliminated by a little sand on the surface. One thousand pounds was a big load over this sand road before it was improved, but now 3,000 lbs. is a very ordinary load.

"In 1909 five miles of sand-gypsum road was constructed, a very heavy clay was used which contained about 20 per cent. of gypsum and 15 per cent. of gravel, and it has made a very fine road. The road was left for the traffic to mix the materials and $50 per mile has been spent in dragging, shaping up and repairing the weak spots. The road is dragged after every rain and high wind. A 6,000 lb. load on the wagons with 2-in. tires is often seen on this road. It used to be a three-hour drive over six miles with two horses in a buggy."

322. Study of Sand-Clay Materials. — One of the best earth roads is the sand-clay road — when it *is* good, and it is found in all degrees of goodness. In some the surfaces can hardly be surpassed. Under ordinary rural traffic some have notable durability, while others are relatively poor. The reasons which make one sand-clay road good and another inferior lie in the nature and composition of the sand-clay mixture. The precise analysis of sand-clay mixtures having known service records, to determine what made one serve well and another less well, has but recently been adequately undertaken.

Where these are not tests of artificial mixtures but are analyses of natural mixtures in service, the value of the results is greatly enhanced. Directions for conducting sand-clay analyses are summarized in the following paragraphs.

It may be taken as a broad and easily applied rule that sand which in size and grading of particles makes the best cement mortar will also make the best sand-clay mixture for roads.

Elaborate investigations have been made by the Highway Department of the University of Arizona, including a study of the Georgia roads, to determine the proper proportions of sand-clay mixtures to yield the best results as to durability in all weathers, and absence of mud and dust.

323. — First a study was made of sand-clay roads already constructed, as to life, present conditions, traffic, and cost, and the physical properties of sand and clay used in them. Twenty-five hundred miles of sand-clay roads some time in service were thus investigated. Definite information could be secured covering materials, methods, and behavior of the road at all seasons. Nine hundred samples of materials were collected and examined in the laboratory.

324. — There were five steps in the analysis: (*a*) Separating sand from clay; (*b*) mechanical analysis of the sand content; (*c*) slacking test on cylinder of sand-clay; (*d*) examination for mica and feldspar; (*e*) slacking test on clay cylinder.

After pulverizing the sample only that part was tested which would pass through a No. 10 screen (i.e., ten meshes to 1 inch). Having taken a known mass of the

mixture, the clay and sand were separated by washing. The sand was then graded by screens of 20, 40, 60, 80, and 100 meshes, and the percentage of each grade noted.

The soil-slacking test indicated the resistance of the material to water. To make it a cylinder of the material of stiff pasty consistency 1 in. in diameter and 3 in. in length was made and dried. Then it was immersed in a jar of water and the time noted for it to disintegrate. The most durable mixtures, in general, are those which take longest to break down.

Mica and Feldspar, unless in quantities greater than 5 per cent., will do little harm and if in large quantities can be detected by the eye and touch.

The slacking test in clay is made after the sand has been removed. It is conducted in the same manner as the soil-slacking test and is used to determine a clay's value for binding. If it disintegrates in less than two minutes it should be considered as doubtful unless the soil was slow in disintegrating.

325. Conclusions. — From observation of roads and laboratory analysis, the following conclusions were reached:

The total relative sand content, disregarding the size of the grain, is no criterion of value. The sand smaller than the No. 60 is of little value and No. 100 size is detrimental if there is much. But since the best natural mixtures do not have clay enough to fill the sand voids alone it is evident that a part of this space is filled by the finest sand. Undoubtedly this fine sand is more useful, too, in this position than an equal amount of clay. The greater the proportion of coarse to fine sand the harder and more durable will be the road surface, provided the coarse material is hard, strong and non-crushing. If soft for any reason, its use is undesirable. There can be no doubt that in wet weather the strength of the road depends primarily on the sand, and graded coarse sizes are better than uniform fine sizes.

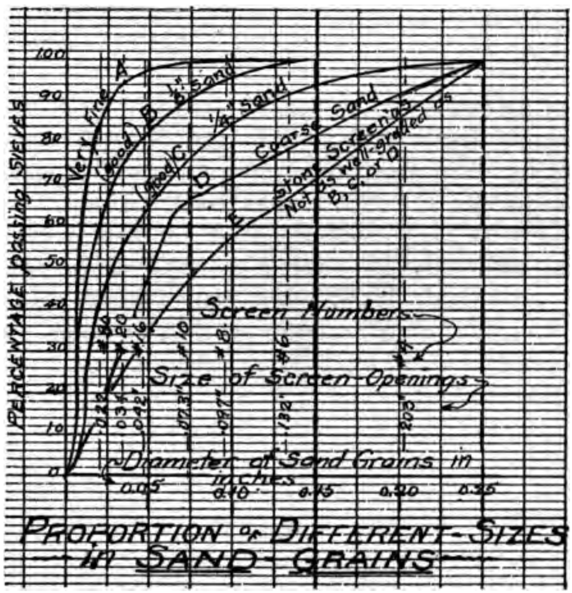
For the best results with sand-clay mixtures, the sand smaller than No. 10 and larger than No. 60 should not be less than 45 per cent nor more than 60 per cent of the dry sample. In addition, the sand smaller than No. 10 and larger than No. 60 should be composed of about equal parts of Nos. 20, 40, and 60. Material coarser than No. 10 is classed as gravel, and 10 to 15 per cent of this is desirable.

Test cylinders of sand-clay mixtures, 1 in. by 3 in. long, should, after having been dried in a steam bath of 212° F., take at least two minutes, when immersed in water at 40° F.,

to crumble and fall down to the natural slope of the material and preferably should take six minutes.

The clay cylinder should show as much resistance to water as the soil cylinder if it is a good binder. It could be used with good results, however, if the soil cylinder showed greater resistance.

326. Tests of Sand for ordinary uses, such as for mortar or concrete, should also be regularly made on work of importance. The importance of its quality as bearing upon the success of the mortar or concrete has only been appreciated of relatively recent years.



Obvious tests have been for *cleanness*, when the material was carefully washed, and its weight before and after compared, after drying in each case; gradation of *sizes* determined with sieves ranging from 10 to 100 meshes to the inch; determination of *voids* by pouring measured quantities of water into known volumes of sand; *tension* and *compression* tests on cubes

and briquettes of mortar; and *microscopic* tests for shape and cleanness of grains. Of these, the first and second tests are regarded as most important. The diagram herewith illustrates the proportions of various sizes in five different sands. Samples B, C, and D would be classified good, especially C, while A and E are poorly graded, hence poor for practically all engineering and highway work.

CHAPTER XIV

ROAD BUILDING WITH OILS

When any of the mineral particles of a road are fine and dry, there will be dust. Dusty roads are bad. If there is no native medium for holding this fine dust in place, mineral oils, or bitumens, have been successfully used. Much has been heard about this treatment for maintaining stone-road surfaces under auto traffic, and now similar methods are coming into use on earth roads. This chapter summarizes the present practice and experience of a half-dozen States, and mentions a few other dust preventives.

327. Oil-Sand Roads. — There are considerable sections in Oklahoma and other semi-arid regions where the surface is largely sand. Elsewhere, we have dealt with the sand-clay-gravel, or "top-soil" road, as it is called in the South Atlantic States. Many sections, however, have great stretches of deep sand roads where there is neither suitable clay nor gravel available for improvement into one of those types, nor any cementing material such as gypsum, promising any good results. It seems, therefore, that there is an especially fruitful field of investigation for the improvement of these roads with oil.

328. Historical. — Light or crude oils of various sorts were proposed for keeping down the dust on macadam roads in the Eastern States almost as soon as the automobile began to make itself felt. It was soon seen, however, that a more substantial material was necessary. This first led, in France and England, about 1900, to extensive experimentation with coal tar upon their macadam roads. The same practice became prevalent in Massachusetts about nine years ago and then spread into nearly all of the progressive states with the growth of automobile travel.

329. Use of Bituminous Materials. — Coal-tar and the various grades of asphalt are commonly classed as bitumens

in road building, and several standardized methods of use have been perfected. One method simply makes a surface application of bitumen to old macadam roads. Another is the mixing of crushed stone with hot bitumen and spreading it on the road when it might be called bituminous macadam, bituminous concrete, asphalt macadam, Bitulithic (which is a trade name for a bituminous concrete), etc.

330. Asphalt Pavement. — The well-known sheet asphalt pavement of cities, expensive to lay and expensive to maintain (the source of untold graft), contains approximately 10 per cent asphalt or bitumen and 90 per cent of sand, fine clay and dust, thoroly mixed, heated, spread on a concrete foundation and rolled. It should be noted here that asphalt, being a natural product, has the property of solidifying which coal-tar, being a distillation product from coal, does not have, at least to the same extent. It should be further noted that the sheet asphalt pavement has usually a 6-in. base of concrete but a wearing surface of only 2 to 3 in.

331. Country Roads. — The above conditions are very different from those to be found on a country road and our discussion must proceed accordingly. That is to say, if we are to use a surface of sand and asphalt upon a country road we must have an infinitely better-prepared foundation or subgrade of earth than is common. The asphaltic surface-layer must be thicker than upon the concrete base, or else the surface must be maintained by additions of top dressing whenever depressions or settlements occur. With these limitations there is no reason why some asphaltic treatment of country roads is not a feasible proposition, and at a cost probably not prohibitive.

332. — Before leaving the pavement types, however, attention is directed to the so-called bituminous carpet. It is by many advocated and deemed essential to protect the surface of concrete pavements such as have within the last two to three years been built upon certain country roads in the Northern States adjacent to large cities where heavy motor and horse travel existed. While the concrete pavement was first regarded *as the* solution of all pavement troubles it was soon evident

that its surface was likely to be easily chipped, hollows and rough places were quickly worn in it, — hence the necessity of the bituminous covering as just suggested. In this case the hot asphalt or bitumen is spread over the surface in a thin sheet and coarse sharp sand immediately spread over it to absorb it, the two materials forming the protective carpet.

333. Cape Cod Roads. — Reverting now to the country roads, we may learn from the experience of Massachusetts. Cape Cod is at the end of a long arm of land reaching out into the ocean, the eastern 40 or 50 miles of which are practically all loose beach sand. Inasmuch as this territory is mostly a great summer resort the road problem became still more acute with the advent of the automobile. No clay or coarse gravel being available, the effort was made to bind the material with grass roots but with no success. The United States Office of Public Roads sent special agents to investigate the problem and a solution has finally been reached by heating and thoroly incorporating heavy asphalt with the sand in pug-mills, in effect binding the asphalt and sand into an asphaltic pavement.

334. California's Experience. — During the past ten years a great deal of experimentation and construction with asphaltic oils has been carried on in the dry sections of California, also. It was first observed that the dry sand and dusty soil around the oil wells soon became, through the waste or leakage of the crude oil, to resemble asphaltic pavements. It should be borne in mind, however, that the California oils are especially rich in asphalt, the percentage running as high as 70 to 80 or more in some cases. It has further been found by countless experiments that if petroleum has either a paraffine base like the Pennsylvania oils, or one in which there is considerable paraffine as well as considerable asphalt, as in the oils of northern Oklahoma, its use for road purposes meets with little success. The paraffine appears to lubricate the sand instead of binding it together.

335. Petrolithic. — California has built many miles of road, especially in the irrigated fruit growing districts where the sand and dust was formerly several inches deep, by what is

called the Petrolithic method. The process may be essentially described as follows:

After the road is graded, where necessary, the soil is ploughed, harrowed and thoroly loosened to a depth of about 10 in. In this loose state the oil is spread on to a quantity of about one-half gallon per square yard. It is harrowed and cultivated for a long time until the oil has been thoroly mixed-in, then a special rolling tamper is put to work. The tamper is a patented device and operates to pack the bottom of this loose layer before the top. Successive thoro cultivations and mixing take place and the use of the tamper is continued until a layer of well-oiled soil is produced from 6 to 8 in. in thickness, supported, moreover, on a substantial and well-built sub-grade.

Upon the advent of this method extravagant claims were made for it, as of every other good thing. Of course, also, there were many failures or partial ones, while the technique of this kind of work was being learned. It is also clear that there is no mystery about the effects of this oil and that the success or failure of such a road largely depends upon the size, shape, hardness and general physical character of the mineral materials used. That is to say, materials which would bind well naturally have their binding qualities considerably assisted by asphalt. Those which are extremely deficient in binding qualities probably will not prove successful in any road under hard service.

336. Oklahoma's Position. — Since Oklahoma oils have been for a number of years shipped to eastern markets for road use, in such States as New York, New Jersey, Massachusetts and Connecticut, apparently here is a field worth thoro investigation for their use in sections where other road building materials are deficient. It may be suggested that their uses will be found in two fields: (1) in applying oil to sand roads, or of soil deficient in binding power, as already suggested; (2) possibly to form a bituminous carpet when later in our development macadam roads shall have been built in those sections containing rock suitable for this purpose. Then an increasing automobile traffic will doubtless demand such a use.

337. Oklahoma Asphalt. — Before speaking further of the characteristics of suitable road oils, attention should be directed to the "Rock asphalt," so called, wherein Oklahoma has a vast and unique source of potential wealth, both for *building her own roads* and for exporting the materials to other states. It was

A village street. Note where the oil stopped.

Same road, with and without oil. (Iowa.)

long ago found that an asphalt-limestone, that is, a limestone naturally impregnated with asphalt, mined in the valleys of Northern Italy, made an extremely durable paving material. This led to the invention of modern asphalt pavement, — which is but an imitation of this natural product. Kentucky has mined, on a small scale, asphaltic sandstone with which she has built roads under the name of Wadsworth macadam. But since the supply was limited the cost was so great that only a purely local development has been made.

The reports of the Oklahoma Geological Survey indicate that in asphalt rocks, such as limestone and sandstone impregnated with asphalt, Oklahoma's resources transcend those of any other state in the Union and possibly of any other country in the world. Such being the case, would not investigation and study along these lines be amply repaid? The commonwealth has within her boundaries unlimited quantities of this material to be had at a moderate cost but which other states must perforce transport long distances and at a high cost.

338. Oil on Earth Roads. — To further illustrate its application in detail the following quotation from the California Highway Department (1906) is made:

"The oil is simply sprinkled on the road, laying the dust and incidentally hardening the surface. Alkali soils disintegrate the oil and destroy its binding qualities. A sandy loam is the most suitable for treatment, usually giving good results when properly treated with an oil of good binding quality. Clay is probably the worst of all, as it does not absorb the oil well and exhibits a tendency to ball up and give trouble; sand should, therefore, be added to the clayey surface. Special attention should be paid to drainage, as the roadbed is to be dry when the oil is applied.

Another method. — The road is first plowed to a depth of 6 in. and properly crowned; all clods and lumps are broken up by means of a harrow, and the roadway well sprinkled with water; a specially constructed rolling tamper is then used by which the lower portion of the loose earth is compacted to a depth of about 2 in. except in cases where the sub-grade is unusually firm. After the lower portion is made firm, a heavy asphaltic oil is applied, 1½ gallons per sq. yd., and a cultivator passed over the road until the oil and earth are thoroly mixed. The tamper is then used again, and the road is further compacted until only 1½ in. of the loose material remains on top. Oil is again applied, and the surface rolled with the tamper until firm, and finally it is ironed down with an ordinary roller, with additional application of earth to take up any excess of oil. A road constructed in this manner will require from 2½ to 3 gallons of oil per sq. yd. It is hard and dustless and resembles asphalt. California oils are the best. Texas and Kentucky oils cost from 4 to 8 cts. per gallon. The residuums and special preparations vary from 2 to 12 cts. This seems to be a modification of the Petrolitic method.

338A. Kansas Oiled Roads. — In 1915, the State Engineer described their methods and results as follows:

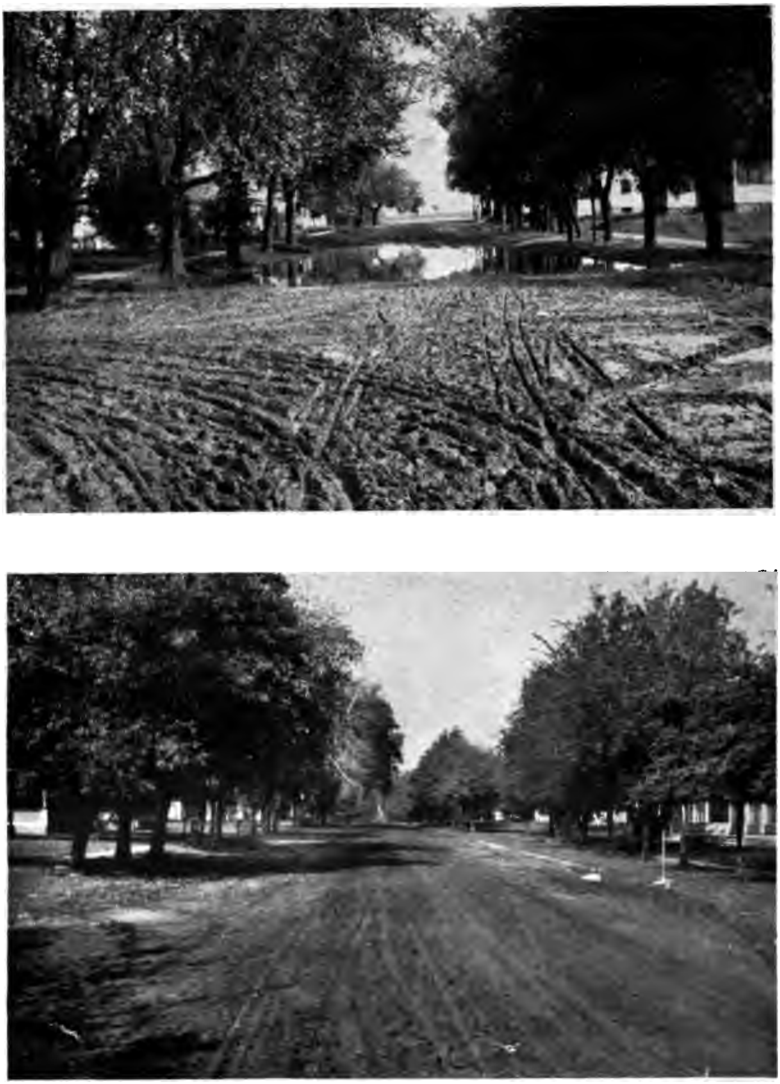
"A shoulder furrow is plowed on each side of the roadway, to be treated, from 16 to 18 ft. wide, and the loose earth is graded outside of it. If there is too steep a crown the center is plowed and the material thrown out to the sides. By plowing

only the shoulders it is easy to shape the sub-grade to a crown of about 1-inch to the foot. Practically the same care is exercised in preparing the sub-grade as for macadam. The use of the solid shoulder prevents the oil from spreading and facilitates the mixing and tamping process. Sandy soils are best adapted to the oil treatment, but satisfactory results are obtained on clay and heavy gumbo if the earth is thoroly pulverized.

"The grade of oil used is much more important than the kind of soil. Light oils and those having a paraffine base are little better than so much water. The oil should have an asphalt base of at least 85 per cent, free from paraffine and all lighter oil, and be applied to the road at a temperature of not less than 250° F. Such an oil needs heating before it can be taken from the tank cars. They usually have special steam coils for this purpose. Three hundred and forty degrees Fahrenheit in the car permits the oil to be delivered on the ground at about 250° F. This requires a steam pressure of 100 lb. per square inch.

"**Application.** — After applying $1\frac{1}{4}$ to $1\frac{1}{2}$ gallons of oil on the rolled sub-grade, sufficient earth is graded on top of the oil to absorb it. For a treatment of $1\frac{1}{2}$ gallons to the square yard about 4 in. of loose, fine earth is applied over the oil, and thoroly soaked with water from a sprinkling wagon, and the tamping process begun. A disk harrow, with blades set at an angle, and a drag are employed to stir and mix the oil with the earth. The harrow and drag precede the tamping roller. As soon as the first course is thoroly mixed the operation is repeated. The earth used should be just enough to absorb all the oil. When the tamping roller rises to the top and the surface has been thoroly compacted a water-tight wearing surface of from 5 to 6 in. thick will have been formed. Should any surplus oil come to the surface after travel has been allowed on the road, a small amount of loose earth is thrown on to absorb it. The surface of the road may be made more durable by the application of 1 in. of sand or gravel.

"There is very little danger of using too much water. The *wetter* the materials the more thoroly the oil and earth can



In the same town,— on the same day. Oil made the difference.

be mixed. Oiled earth roads cannot be constructed successfully without thoroly pulverizing the earth. Treating the surface with oil is not satisfactory, except for laying the dust, and this only for a short time. Oiled earth surfaces are not satisfactory for city streets on account of the oily dust. In Kansas the actual cost of the materials and the construction of oiled earth roads as recommended above is shown to be [illegible] to [illegible] cents per square yard, averaging about [illegible] cents."

330. Oiled Roads in Iowa. — This State is looking into the possibilities of using this material at least upon village streets. It finds that an oiled road will not stand up very long under severe traffic in dry weather, but that it is distinctly worth while as a dust and mud preventive or palliative. Like all other road improvements there are circumstances which render it appropriate, as well as others where the contrary is true.

Its usefulness has been found to depend upon the character of the soil and upon the body, or stickiness, of the oil applied. Thus if sand or gravel are applied to clay or loam, with the addition of oil, there is a great improvement of the surface, proportionately less as any of these elements are lacking. Whatever the soil, complaints usually arising from the temporary "nastiness" of the surface mixture were vastly lessened, and the surface equally improved by the immediate application of sand to the surface following the oil. Residents naturally object when dust and oil from a fresh surface is tracked into houses, soiling clothing and carpets, so considerable care in this direction is necessary and justifiable.

If all traffic can be kept off new work for at least twenty-four hours, permitting it to thoroly soak in, it is a great advantage. A penetration of about one inch may be expected from the first application, and if followed up for several years may amount to five or six inches. This increases the stability and water-proofness of the crust, and yields the best results. Several views herewith illustrate results in an Iowa village by three methods.

Like other kinds of road work, it is easy to waste money and get no results in oiling roads. It is useless to apply it unless there is first constructed a first class, thoroly com-

pacted road surface, true to line, crown, and grade, — a construction of considerable stability in itself. The oil is best applied after a rain, when the surface is well dried out, but before any appreciable dust has formed. If there is much dust it should be scraped off. To secure best results, the oil should be applied hot. This is because in the first place the oil which is heavy enuf to require heating to flow freely will have a heavy body; and secondly, applied hot it will have a much better penetration. The cost, in Iowa, is that of one-half gallon per square yard per season, or about two cents (oil at four cents per gallon). An ordinary street-sprinkling wagon has been used with success, care being taken to secure as even a distribution as possible. For more elaborate undertakings, especially with hot oils, tanks designed to be heated by steam from a traction engine or roller, and distributing the oil under considerable pressure are on the market, and give better results, especially with stone road surfaces. The cost of application is about two cents per square yard, also.

The nature of the oil to be used cannot be adequately discussed here. In fact the petroleums are so complex chemically, that the selection of a suitable road oil is more a matter for a chemical than a civil engineer. Many oil refining companies, however, are specializing in the production of oils for road work, and since it is to their interest as well as the consumers to get the right product, it may be expected that their advice can be pretty safely followed in this respect.

340. Dust Preventives. — Until comparatively recent years, if properly constructed of suitable material, the macadam road was theoretically correct and practically sufficient to withstand the average traffic of our rural communities. It was dependent for its bond upon moisture and upon the dust produced by traffic, and so long as this dust remained upon the road surface to be washed into the interstices by occasional rains, a macadam road gave excellent and satisfactory service. With the advent of modern, fast, motor traffic, however, these roads deteriorated rapidly. The rubber tire created practically no dust, but raised such as there was and allowed it to be carried away from the surface. This displacement not only robbed

the road of valuable binding material, but created a menace to the health and comfort of the community. To find a remedy soon became of paramount importance. We have at present a great variety of materials for the purpose of laying the dust and thus tending to preserve the surface.

Of course water has been the best known and most generally employed dust preventive. It effects a mechanical bond between the particles of dust and rock, and with certain types of rock it has been shown to develop a weak chemical bond with the formation of colloidal cementing materials. The effect, however, is only temporary, and under heavy motor traffic in dry weather continual sprinkling is necessary, which soon becomes an expensive item.

341. Sea Water has been tried with better success, owing to the fact that certain magnesium and calcium salts contained in it are capable of retaining moisture for a considerable length of time. The large amount of common salt also contained forms an objectionable feature to sea water, since in wet weather it leads to the formation of a salty mud which is injurious to the paint and iron work of vehicles.

342. — The good results of sea water without its disadvantages are obtained by the use of *calcium chloride* which is obtained as a comparatively cheap by-product in the manufacture of soda by the ammonia or Solvay process. This material was formerly applied in solution, but recently it has been prepared in a fine granular form to be spread over the road surface in a thin layer. It takes up moisture immediately, giving the surface a damp appearance, and proves quite efficient where the average moisture in the atmosphere is sufficient to feed the salt. Otherwise, an occasional light sprinkling with water is necessary. The salt is, of course, washed away by repeated rains and must be replenished from time to time. The cost of the treatment is largely dependent upon local climatic conditions.

343. — The greatest development in the preparation of dust preventives has been made in utilizing *bituminous products* such as petroleums, coal-tars and water-gas tars. These materials were first used in their crude state, but the results

were only partially satisfactory, so that now we use refined products almost entirely.

A clean, practically dustless surface is the prime requisite for any form of successful surface treatment, and neglect to have such a properly prepared surface is too frequently responsible for unsatisfactory results. The surface should be reasonably clean for the application of a simple dust-layer, since it is not the purpose of such an agent to lay any quantity of dust which may be present on the road, but rather to hold the products of wear for a period after the application has been made.

This brief discussion of an important topic, will, it is hoped, prove at least suggestive and stimulative to the student.

CHAPTER XV

NEEDED LEGISLATION

Sound, constructive legislation must form the basis for any comprehensive and economical plan for road construction. For success there must be *organization, leadership, and money.*
This chapter suggests fundamental needs in legislation, not for any particular State, but for *all* States, if the "good roads" movement is to rationally progress.

344. — Since the sovereign people express their will by the enactments of their representatives, supposedly, and since road-building is so pre-eminently a public enterprise, it follows that sound permissive and creative legislation must be at the bottom of successful effort in this direction. Simple as this proposition seems the enactments of the past twenty years do not indicate that its meaning is at all fully grasped.

345. — The American Highway Association has, thru certain experts, compiled the road laws of the several States, and reports that an almost unbelievable amount of dead timber encumbers the statute books in this regard. Remarkably, too, it is often the smallest States which have the most curious and voluminous array of literary curiosities dignified by the general name, "road law." Fortunately, there is now a distinct movement toward codifying and simplifying the road laws in many of the States. A State Highway Department, when created, must affiliate and harmonize with all the other governmental functions and bureaus of the State. These differ widely according to the constitutions governing the various commonwealths, and are affected by general laws otherwise enacted. It follows that there can be no "cut-and-dried" plan, or code, which will fit every state irrespective of these collateral requirements. *Each must be* worked out in the light of best practice and

experience obtained in that or other States under similar conditions.

346. — It may be confidently asserted, however, that good roads can be built, maintained, and financed with a reasonable and fair distribution of the burdens if the laws, whatever their length, language, or context, embody and express, even tho poorly, a relatively few fundamental principles. It is the present purpose to enumerate and comment upon a few of them, in the hope that the suggestions made may prove helpful to those upon whom this onerous task of framing "good road" legislation may fall. By implication, it will be seen that the whole of this text aims at this very point. Wherever the described result is worth while, or wherever the means of accomplishing it are direct and well-known, it is plain that the problem is simply to provide legislative language which will permit or compel that result alone. This remark must cover the very numerous matters which can not be alluded to here. In general, the shorter the road law, the better it will be, providing, of course, fundamentals are adequately covered.

347. Code Essentials. — To build good roads, economically and upon a large scale, three broad elements must be present in the State's road laws.

1. There must be created an adequate *organization*. This means workers enuf, tied together in co-operative effort, animated by a common purpose, profiting by each other's experience, in numbers proportionate to the work before them.

2. There must be provision for adequate professional skill and intelligence in the *leadership* of the organization. This means progressiveness enough to keep abreast with the best practice elsewhere, and aggressiveness enough thru and by which the leaders will solve their own special problems in the best way, conducting entirely original investigations if need be. This sort of leadership costs money all along the line.

3. There must be ample amounts of *money* provided capable of being spent in the light of the best experience. It should be amply safeguarded, but freely spent nevertheless, and as a competent "general staff" or commander-in-chief

deems most expedient. The final aim under all three heads is to insure the taxpayer's getting actual value received for his money.

348. Organization. — To begin at the top, there is needed a State Highway Commission, non-political in its nature, preferably containing non-political appointees from other state departments, as from its higher institutions of education.

The Commission is to be a legislative and judicial body. Executive power should be vested in a Chief Highway, or State Engineer. He should have as many assistants as the work fairly demands, judged by usual commercial standards, and should be permitted to organize his work among them by special departments, to get effective and economical results.

Some States are so economical that they give him one assistant engineer and a stenographer, while others find they are saving large amounts of money by giving him a headquarters force of thirty or forty with a field force of a hundred more, tho spending less than twice the amount than in the first case.

All of these persons should be *appointed*, should work under permanent tenure during good behavior and effective discharge of their duties, and should receive pay commensurate with securing the complete efforts of the best class eligible for these positions. Since they will be educated at the State's expense in any case, why should not the State retain them so as to profit by their special knowledge so gained?

349. Leadership. — There must be, especially in the upper ranks of the organization, such a degree of intellectual activity as will be quick to perceive new and advantageous expedients on its own part, and to recognize and encourage similar activities in the minds of subordinates. There must be sound professional attainments, and upright, confidence-inviting character. Civil Service, and the merit system, honestly and fairly administered, with substantial technical qualifications required of non-political appointees, promise the best results in this direction. This sort of leadership is *worth what it costs*, whatever that may be, and the cheap man is dear at any price. Such *leadership should* have specific control of all road work wherein

the State is directly a party, and general control and supervision of all road work in the State.

350. Available Funds. — Road-building at its best requires large amounts of money. It may be raised by distinctly local taxes, or by State taxes which spread the burden wider, by combinations of the two, or combination of either with revenue derived from special taxes on automobiles. Money simply *must* be forthcoming, and in substantial amounts, or any amount of good roads talk profits nothing. To build good roads there must be plenty of money; but it is an economic waste and crime unless it is expended with all possible safeguards to insure that the public is getting its money's worth. But this presupposes all that has gone before in this particular discussion.

351. Specific Topics. — Having dealt with the generalities of road legislation, a brief list of topics which should be incorporated is also appended, with brief comment on each. These are among the things most needed:

(*a*) Compulsory appointment of highway engineers, or highway commissioners with suitable qualifications, in each county.

(*b*) An adequate and uniform system of financial records and of cost accounting thruout the State, that waste and extravagance may be detected and checked. This implies the establishment of a complete statistical bureau, by which cost-analyses and benefits obtained can be checked against each other. This means economy.

(*c*) Appointment of road overseers for townships, or less than county units, by the county board or commissioners subject to removal at any time for unsatisfactory service, — otherwise to be continuously employed.

(*d*) Supervision of the expenditures, important contract lettings, and administration of county road funds by the State Highway Commission, operating to harmonize their plans, and prevent costly and wasteful experimentation. Thus work may be done *right the first time.*

352. — (*e*) Authorization of special road districts for constructing costly hard-surfaced roads, and for dividing the costs according to the benefits.

(*f*) Authorization of bond issues both by county and road districts, with suitable requirements as to their life, maintenance of the work, limit of indebtedness, or other expedients looking to the protection of the investing public.

(*g*) Requiring State Commission to carry on active educational propaganda in all feasible ways, looking toward the advancement of the State's interests in transportation, and the development of her economic resources. Should include definite plan of training and promotion of all road-employees.

353. — (*h*) Abolition of the "labor tax" for country roads, substituting a reasonable cash poll tax therefor.

(*i*) Apportioning state taxes so that the centers of population bear an important part of the cost of country roads leading to them.

(*j*) Classification of the roads in the order of their importance, and concentration of funds on those bearing the bulk of the traffic, such classification to be based upon a comprehensive study of traffic requirements and consideration of the economic development of the areas involved.

(*k*) Requiring an economic survey for the location of and determination of the quality of all deposits of road materials in the state, and providing for systematic study of them in their possible combinations to ascertain the most economical practice for their use, and establishment of standards of quality to which they must conform before being permitted to be used on any state-control road.

(*l*) Standardization of bridge plans, stating requirements to which all bridges in State must conform, having due reference to actual and prospective loadings, as motor-trucks, tractors, and road-rollers.

(*m*) Provision for systematic, thoro, complete maintenance in each and every class and type of road work, including bridges and culverts. This prevents great wastes of money, and conserves expenditures already made.

354. Civil Service. — The National Civil Service Reform League has studied this topic in relation to highway work, and suggests the following as to the content of a suitable law:

1. A board of three examiners, appointed by the governor for

the Highway Department, for six year terms, removable only after a hearing and statement in writing of reasons for removal.

2. Board of examiners to prescribe, enforce and amend rules affecting the highway service, and keep records of its proceedings and examinations.

355. — These rules should embrace the following points:

(*a*) Competitive examinations for all positions not of a policy-determining character.

(*b*) Creation of eligibility lists, to remain in force two years, containing names of candidates in the order of their standing.

(*c*) Appointment of the person with highest standing on his appropriate list.

(*d*) A probationary period of six months before appointments or promotions are complete.

(*e*) Temporary employment without examination, in emergencies, with consent of board, pending appointment from an eligible list. Same not to continue more than sixty days, nor authorize re-appointment.

(*f*) Promotion to be based upon competitive examinations, and record of efficiency, conduct, and seniority.

356. — 3. In vacancies requiring peculiar and exceptional qualifications of a scientific, professional, or expert character, if competition is impracticable, and the position can best be filled by some person of recognized attainments, the board may by full vote suspend competition, but must enter report of same and reasons therefor in its annual report.

4. Examinations shall be impartial and shall deal with the duties and requirements of the position to be filled.

5. A complete register shall be maintained of all persons in the Highway Service when such law takes effect, and subsequently, and show all changes in their status. Law not applicable as to present incumbents.

357. — 6. No person in the Highway Service or seeking admission thereto to be discriminated against because of his political opinions or affiliations.

7. No officer or employee of the Highway Service to be in any manner concerned, orally, or by letter, in soliciting any assessment, contribution, or subscription for any political party

or purpose whatsoever from any person holding a position in the Highway Service, or from any other person; or take part in any political affairs or campaign, further than to cast his vote and to express his opinions in private.

358. *Conclusions.* — The above discussion of legislative matters are only suggestions to stimulate the study of local conditions by legislators and the general public. There is a current tendency to rush into legislation without duly considering, first, what it is that is desired to be accomplished; and, second, the means by which the desired ends may be achieved. This is probably because road-building in this country has for more than a century failed of recognition as an *art* based on *science*. All the inertia of a century's accumulation of ideas, many of them erroneous, must be now overcome before we can enter an era of true road-*building*. Happily, there is now considerable evidence that progressiveness and science, aided and supported by the wave of motorization sweeping around the world, are rapidly undermining this inertia.

The inertia in legislative matters, whose vital importance has just been suggested, has also been due, probably, to the predominating type of membership in the legislatures of the great States where road problems pressed hardest. It has been chiefly made up of lawyers and farmers.

The real building of roads is exclusively an engineering problem, and a training in law touches it no more directly than any other of the manifold interests in life. The farmer, despite the notion of many to the contrary, doesn't necessarily know anything in particular about *how to build* good roads. These are further reasons why our legislatures lag in progressive road enactments. Under the circumstances it might not be inapt to call upon the engineer for assistance. It is to assist in disseminating correct information upon the many phases of road-building among these legislators, the vast army of minor road officials, and among the public generally that this text has been prepared.

Time alone will gauge the success of the effort.

EPILOGUE

The student or reader who has given careful attention to the preceding text, who has sought to verify the connection between the numerous facts stated and principles enunciated, can hardly fail of becoming a "good roads" enthusiast. He will find it merely a stepping-stone and introduction for more extensive inquiries and circumstantial investigations in the field immediately surrounding him. It is hoped that this text will assist him more readily to secure an orderly arrangement and correlation of far-reaching economic principles than would otherwise be easy, and that his deductions may be more sound and effective because of it. As he studies, one thing will constantly grow upon him: There is no more outstanding fact in history, from the Roman to the Uhlan, than that good roads and free communication spell *progress*, *enlightenment*, and *civilization*. The lack of them means barbarism.

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